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ABSTRACT

This report describes the radioactivity at Rocketdyne's Santa Susana Field Laboratory (SSFL), and puts the information into perspective to permit readers to make an informed evaluation of the SSFL situation for themselves. Emphasis has been placed on the presentation of facts which clarify and/or quantify: (1) the history of nuclear operations at the SSFL; (2) the regulation of those operations; (3) the amount of radioactivity that has been removed from the site; (4) the amount of radioactivity remaining; and (5) Rocketdyne's plans for both ongoing cleanup and operations.

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1.0 EXECUTIVE SUMMARY

This report describes the radioactivity at Rocketdyne's Santa Susana Field Laboratory (SSFL), and puts the information into perspective to permit readers to make an informed evaluation of the SSFL situation for themselves. Emphasis has been placed on the presentation of facts which clarify and/or quantify: (1) the history of nuclear operations at the SSFL; (2) the regulation of those operations; (3) the amount of radioactivity that has been removed from the site; (4) the amount of radioactivity remaining; and (5) Rocketdyne's plans for both ongoing cleanup and operations.

This document was generated by means of an extensive review of historical data and reports for each of the SSFL facilities, a review of recent documented radiological surveys, and conservative calculations. Where comparisons are made to other operations or environments, published data sources are cited. The methodology and data used in the calculations are presented.

Nuclear operations at the SSFL have always been relatively small and carefully controlled. The reactors have been small, and they have operated at low power levels. An environmental monitoring program has been in effect since 1956 to control all nuclear operations. Nuclear operations at the SSFL have been phasing out since the mid 1960s, and the Department of Energy (DOE) and Rocketdyne have been cleaning up the phased-out nuclear facilities in accordance with budgetary and programmatic constraints, while maintaining the laboratory in a condition which assures that there is no risk of exposure to the public. The decontamination and decommissioning work began in the late 1960s, and became very active in 1974. As a result, the SSFL is much further along toward full cleanup than most other nuclear development sites in the country. Almost 90 percent of the contaminated facilities, involving more than 99% of the total radioactivity generated, have now been cleaned up. A plan to complete this work exists and is being implemented. In this context, cleaned up means releasable for unrestricted use (i.e., available for any suitable use.)

The following summarizes the Rocketdyne Santa Susana Field Laboratory situation:

- Radioactivity at the SSFL has resulted from the operation of ten reactors and seven criticality test facilities, from fuel fabrication, from reactor and used fuel disassembly activities, from small-scale laboratory work, and from the on-site storage of nuclear material.

- All 10 reactors, 9 of which had power levels of 1 MWt (megawatt thermal) or less, and all 7 of the very-low-power criticality test facilities have been dismantled and removed from the SSFL.

- Over 30 years of nuclear operations at SSFL have resulted in the generation of approximately 135 million curies of radioactivity from approximately 7200 equivalent MW-days of total reactor operation. Although the amount of radioactivity appears formidable, it represents about 16 lb of mixed fission products plus a smaller quantity of transuranic isotopes. This quantity would make a cube no larger than 6 inches on a side.

- For perspective, this total level of radioactivity is equivalent to one-half of one percent of that present in a typical large commercial light water reactor (LWR) after 1 year of operation.

- Almost 90% of the total SSFL radioactivity was generated by one reactor, the 20 MWt Sodium Reactor Experiment (SRE). This reactor was decommissioned and removed from the SSFL, and the site was decontaminated and released for unrestricted use in 1982.

- In total, more than 99.9999% of all the radioactivity generated at SSFL has been removed, via a combination of natural radioactive decay, transportation of spent reactor fuel off site, and a cleanup program over the past 15 years that has cost more than $25 million. The material which has been shipped off site was sent to approved disposal facilities.

- By way of contrast, published decontamination and cleanup programs for other nuclear development sites involve billions of curies, at projected costs of billions of dollars. In most instances, decontamination and decommissioning of these sites has just begun.

- The total amount of artificial radioactivity in the form of activation products and contamination still present at SSFL is about 60 curies; over 99% of this is contained in a controlled manner in activated or contaminated structures which are locked, fenced, and within a guarded perimeter. There is calculated to be less than 0.1 curie that is unconfined; that is, not fixed in place within structures.

- The unconfined radioactivity is present in very low concentration levels in three areas; access to these areas is controlled and restricted in accordance with applicable regulations. Routine surveys show that this radioactivity is not mobile, and is remaining in place.

- For perspective, the conservative estimate of the unconfined radioactivity (less than 0.1 curie) is much less than the radioactivity in the natural environment at the SSFL; the top foot of soil in the 2600 acres of the laboratory contains 300 curies of radioactivity from the natural uranium, thorium, and potassium in the soil and rocks. This is typical of a Southern California setting.

Many of the above findings are graphically depicted in Figure 1, where the curve shows, at any point in time, the radioactivity present at the SSFL that was generated by nuclear reactors. The distinct steps in the graph represent the discontinuation of operations in the SRE in 1964, the last of the Systems for Nuclear Auxiliary Power (SNAP) reactors in 1972, and the L-85 experimental reactor in 1980. A logarithmic scale was used even though it tends to downplay the reduction in activity that has occurred since 1964, in order to provide more information about the recent, lower level operations. The current residual contamination and activation level of 60 curies is predominantly (58 curies) attributed to the SNAP Ground Prototype Test Facility (Building 059) whose final decontamination is already underway and is scheduled to be completed in 1992. Throughput radioactivity brought onto and then subsequently removed from the SSFL site (e.g., fuel fabrication and fuel cleanup activities) is not shown in Figure 1. However, the residual contamination (approximately 2 curies) still present from these activities is included in the current 60 curie level.

In summary, the amount of radioactivity generated at the SSFL over 30 years is small when compared to most nuclear development sites, and almost all of the generated radioactivity has already been removed. The residual radioactivity is confined and controlled in compliance with regulatory requirements.

Although the man-made radiation levels at the SSFL are low, Rocketdyne's future plans call for the continuing decontamination of the SSFL facilities to release them for unrestricted use. A 6-year, $27 million program, described in the Site Specific Plan for the environmental restoration of the SSFL, is underway to remove additional radioactive material.

Since the nuclear program conducted at the SSFL was performed for the benefit of the federal government, the DOE retains the financial responsibility for the remaining decontamination and decommissioning activities to be performed at the SSFL. Completion of the in-progress program on the projected schedule is therefore contingent upon the success of securing annual appropriations commensurate with the level of activity required in each year. In the meantime, the man-made radioactivity at the SSFL is so small that it represents no threat to the health and safety of its workers or the surrounding community. As long as the property remains under appropriate control, this condition can and will be safely maintained indefinitely.

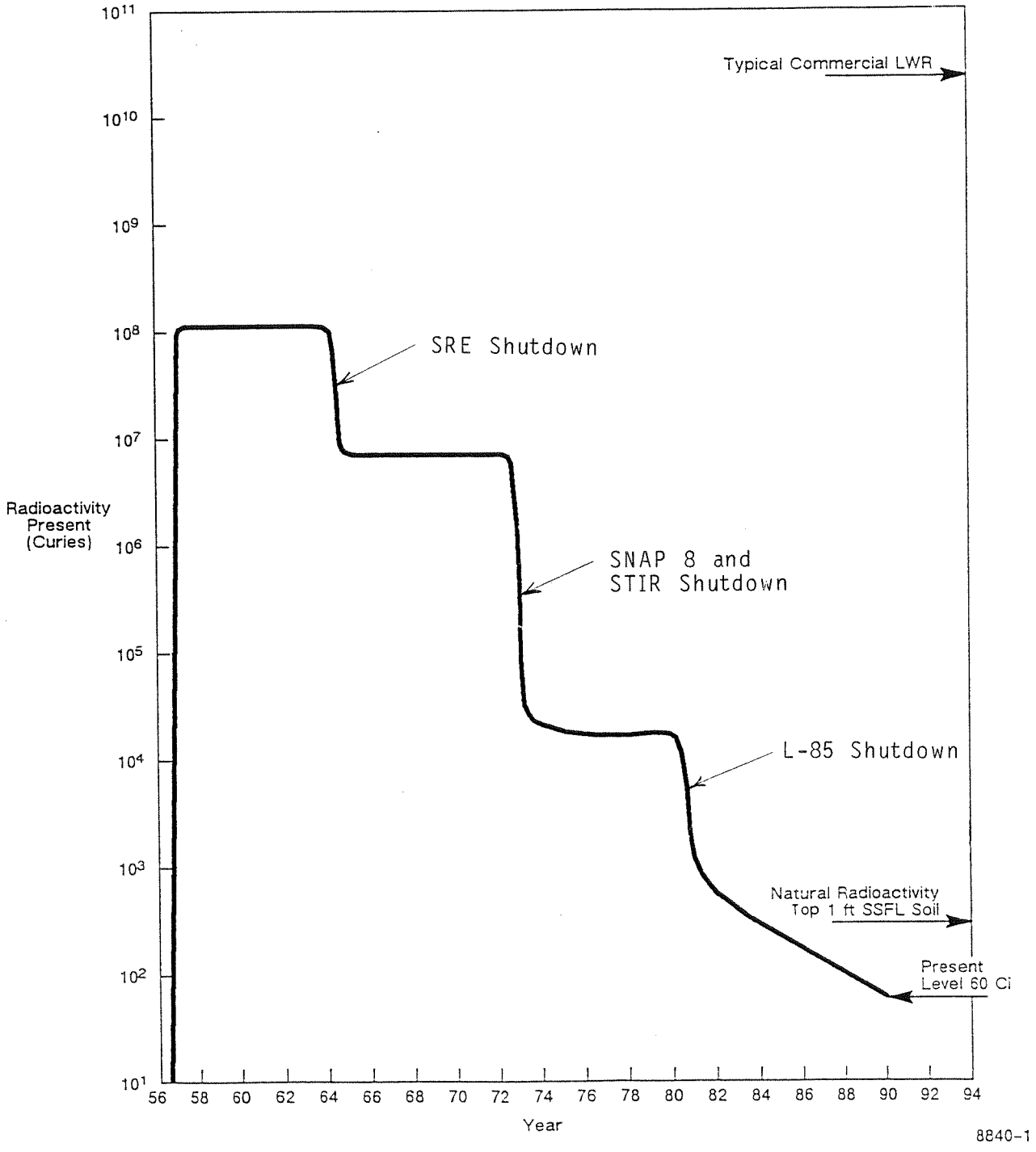


Figure 1. Radioactivity Generated from Reactors at SSFL

2.0 INTRODUCTION

This report has been prepared to inform the public about the nuclear operations at Rockwell's Santa Susana Field Laboratory (SSFL) in the Simi Hills, the radioactivity at the field laboratory resulting from these operations, and Rockwell's plans and activities to clean up this radioactivity. The report is limited to nuclear operations; it presents a description of the radioactivity at the SSFL, and tries to put this information into perspective so that the reader can make an informed evaluation of the situation.

The work done at the SSFL has resulted in many important contributions to the nation's nuclear power programs. Rockwell is justifiably proud of its accomplishments at the SSFL, and of the manner in which it has operated this laboratory.

The report begins with some basic information about radioactivity and how it got to the SSFL. The various types of nuclear operations at the SSFL and how these operations were regulated and controlled is presented next. The final 2 sections then present (1) the clean up operations already completed, and (2) what remains to be done, and the program underway to do it.

3.0 SOURCES OF RADIOACTIVITY AT THE SSFL

3.1 INTRODUCTION TO RADIOACTIVITY

A basic introduction to radioactivity is given in Appendix A, entitled "Radioactivity and Its Measurement." This was taken directly from a report "Disposing of Low-Level Radioactive Waste in California" made available to the public by the League of Women Voters (Reference 1). It is a bit dated, since it does not include a treatment of radon, which has recently been identified as the largest source of background radiation to which the American public is routinely exposed. Otherwise, it provides a concise summary of what radioactivity is, how it is measured, how exposure to radioactivity is measured and the effects of exposure, and what the limits of exposure are, all from the perspective of dealing with low-level radioactive waste (LLRW). As will be shown, low-level waste is the type of radioactive waste at the SSFL.

With the understanding and terminology of Appendix A, the sources and types of radioactivity at SSFL can be described.

There are two categories of radioactivity at the SSFL: natural and artificial. Natural radioactivity is present at the SSFL just as it is present everywhere. Since the surface soil of the SSFL contains measurable quantities of both uranium and thorium, the natural background radiation level there is somewhat higher than in some other parts of the country, but it is not atypical of California locations. The artificial radioactivity is man-made, and results from the nuclear research, development, and production operations carried out at the SSFL over the past 30 years.

3.2 NATURAL RADIOACTIVITY

The natural radioactivity at the SSFL comes from (1) naturally occurring radioisotopes in the soil and rocks, and (2) radioactive products generated by cosmic ray particles, which continuously bombard all parts of the earth's surface. There is also radioactive fall-out from early atmospheric nuclear weapons testing present at the SSFL, just as it is present everywhere. While this radioactivity is not "natural," it is so ubiquitous that it is considered part of the "background" radiation.

The naturally occurring radioisotopes in the soil and rocks have been present in the earth's crust since it was formed, billions of years ago. These radioisotopes have all been decaying away ever since then, but they have such long half-lives that they are still present in significant quantities. Four long-lived natural radioisotopes are present in the soil at the SSFL in detectable quantities: two isotopes of uranium (uranium-238 and uranium-235), one isotope of thorium (thorium-232) and one isotope of potassium (potassium-40). The uranium

and thorium isotopes decay by emitting alpha and gamma radiation and forming "daughter" isotopes, which are also radioactive and decay by emitting beta and gamma radiation to form new radioactive daughters, which decay in turn in three long series of radioisotopes, releasing alpha, beta, and gamma radiation until eventually stable, non-radioactive isotopes of lead are formed. The potassium isotope decays in a single step, by emitting beta and gamma radiation and forming a stable isotope of argon.

Uncontaminated samples of soil from the SSFL show natural concentrations of uranium and thorium of approximately 1.5 and 8 parts per million (ppm) respectively, and potassium-40 levels of 3 ppm. As a result, there are about 300 curies of natural radioactivity from these isotopes in the top foot of soil of the 2600 acres of the SSFL. Similar amounts would be found in any of the surrounding areas.

B Cosmic ray particles are energetic particles (electrons, protons, and heavier particles) which originate outside the solar system and bombard the earth. Some of these particles are captured by the oxygen and nitrogen in the earth's atmosphere, forming radioisotopes. One of these radioisotopes is a form of hydrogen, called tritium. Tritium is also present in nuclear weapons testing fallout, and small amounts are generated and released by operating nuclear reactors all over the world. Tritium is present in trace amounts in water everywhere. It is present in the oceans, in the drinking water in Southern California, and in the ground water at the SSFL. Some of the tritium at the SSFL is thus natural; some may also have resulted from test operations, when neutrons from reactors were absorbed by lithium which is naturally present in the granite aggregate used in the concrete shielding. The tritium in the water at the SSFL is discussed in Section 6.1. Tritium decays rather rapidly; it has a half life of 12.26 years and decays by emitting a very weak beta particle to form a stable isotope of helium.

3.3 MAN-MADE RADIOACTIVITY

The man-made radioactivity at the SSFL came from the following operations:

1. Operation of nuclear reactors
2. Operation of criticality test facilities
3. Manufacture of reactor fuel assemblies
4. Disassembly and inspection of reactors and used reactor fuel assemblies
5. Fabrication, use, and storage of radioactive sources
6. Preparation of radioactive material for disposal
7. Research on reprocessing used reactor fuel
8. Operation of particle accelerators
9. Research using radioisotopes
10. Miscellaneous operations
11. Commercial items which use radioactive materials

The history of nuclear operations at the SSFL is unique, in that it traces the development of advanced nuclear power systems in the U.S.A. nearly from its inception. Many operations were first-ever events; some have led to important on-going developments and some were not pursued further.

The SSFL is also somewhat unique in what was not done there: unlike most nuclear development sites, the SSFL was never used for projects involving any significant aqueous processing of radioactive materials, or projects which generated large tanks of liquid radioactive waste. Radioactive leach fields were never used at the SSFL to dispose of radioactive liquids, and radioactive waste was never buried there.

A map of that part of the SSFL which was used for nuclear energy research is shown as Figure 2. The various facilities which have a radiological history are shown on the map with call-outs. There are 24 facilities marked: A facility may be a single building or even a vacant paved area (the Conservation Yard) or it may be a group of associated buildings and other structures. Many of the facilities were used for more than one operation, and some of the facilities shown no longer exist, having been decontaminated, decommissioned, and removed. Others have been decontaminated and are being used for different purposes now. Also some facility names were changed, even while they were in use.

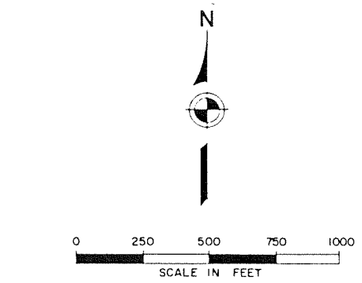
In the discussion that follows, facilities are referred to using the acronyms used in the map call-outs, and also using the building
B | numbers shown on the map.

3.3.1 Operation of Nuclear Reactors

Most of the man-made radioactivity at the SSFL is the result of the operation of nuclear reactors there. A nuclear reactor contains nuclear fuel, usually in the form of fuel assemblies which are made up of fissionable radioactive material (uranium, thorium, plutonium, or a mixture of these) plus other materials which may be added for various purposes, contained within a cladding material (usually steel, aluminum, or zirconium). The fuel assemblies are arranged in a "core", and surrounded by reflectors, shields, and containment vessels. (Two reactors which operated at the SSFL, the KEWB and the L-85, had fuel in the form of liquid solutions of uranyl sulfate.)

When a reactor is operated, atoms of the fissionable material fission (split), releasing neutrons and heat, and leaving behind fragments of the atom called fission products. Some of the neutrons that are released are captured by other atoms of fissionable material, and these capture reactions cause some of these atoms to split, releasing more neutrons and heat and creating more fission products in a controlled "chain reaction." Not all of the neutrons cause fissions, however. Some of them are captured by fissionable atoms which do not

Santa Susana Field Laboratory
Area 4



Legend:
Facilities Already Cleaned up

8849-1

Figure 2. Sites Where Nuclear Activities Were Carried Out at the SSFL

split, but instead form new fissionable isotopes, called "transuranics." Others are captured by the fuel cladding or the other materials in the reactor, and others escape from the reactor and are captured in the shielding around the reactor; far fewer escape the shielding and are captured in the reactor building or the ground.

Most of the fission products from a nuclear reactor are radioactive, emitting beta and gamma radiation. All of the transuranic isotopes formed are radioactive, emitting alpha, beta, and gamma radiation. In addition, when a neutron is captured by a non-fissionable atom, such as in the fuel cladding or the reactor structure or shield, it creates a new isotope called an "activation product". Most of these activation products are also radioactive, emitting beta and gamma radiation.

Operation of a nuclear reactor thus creates 3 sources of radioactivity: fission products, transuranics, and activation products. When part of the fissionable material in the fuel element is used up, or when a reactor is decommissioned, the fuel elements are removed from the reactor. These "spent" fuel elements contain the fission products and transuranics generated by operation of the reactor, and the activation products in the cladding.

The amount of radioactivity generated by a nuclear reactor depends in part on the amount of heat it generates, called its "power level." The heat generated is measured in thermal watts (Wt), thermal kilowatts (kWt; thousands of watts), or thermal megawatts (MWt; thousands of kilowatts). Power levels can range from a few kilowatts (in small research reactors) to thousands of megawatts (in modern electric power reactors). The reactors which have been operated at the SSFL have all had very low power levels: 6 had power levels of less than 100 kWt, 3 had power levels of 600 to 1000 kWt, and one was a 20-MWt test reactor. By comparison, reactors used for commercial electric power generation have thermal power levels of 3000 MWt or more.

The amount of radioactivity generated by a nuclear reactor is not measured while the reactor is operating, but it can be calculated from the power level and other parameters of the reactor. The radioactivity generated per watt of power is a function of operating time. However, an equilibrium is reached after about one year of operation, wherein the amount of new radioactivity being generated is balanced by the decay of short-lived fission products. This equilibrium radioactivity is approximately 6 curies per thermal watt, for a reactor that has operated from one to ten years. This value agrees with the results of a nuclear reactor design computer code (Reference 2). It also agrees very well with a value of 5.6 curies per watt from measured data (Reference 3). Thus, the curies of radioactivity present in a reactor can be estimated (conservatively) by multiplying its thermal power level in watts by 6.

There have been 10 different nuclear reactors operated at the SSFL at one time or another over the last 30 years. These reactors were operated in 7 different facilities. Table 1 lists the name, facility number, facility name, location, nominal power rating, operating period, total power generated (in thermal megawatt-days, MWd) and calculated amount of radioactivity generated for each reactor. A total of 135 million curies of radioactivity was generated in the fuel of the reactors when they were operated; a much smaller amount (perhaps several thousand curies) was also generated as activation products in the reactor vessels, shields, and facilities. A graph showing the quantity of radioactivity at the SSFL as a function of time was shown in Figure 1. As the graph shows, the vast majority of the radioactivity has been removed, but about 60 curies of radioactivity still remains, at a few reactor sites and at other facilities (see Figure 2 and Section 6). A short history of the operation of each reactor is given in Appendix B. The present status of each reactor facility is discussed in Sections 5 and 6.

3.3.2 Operation of Criticality Test Facilities

A controlled nuclear chain reaction can only be sustained when the neutrons generated by fission of the reactor fuel balance the neutrons used up and lost. When the reactor is adjusted so that this balance is achieved, it is said to be "critical". Criticality can be achieved in many ways: by bringing parts of a core of fissionable material together (to reduce the number of neutrons which escape), by removing control rods (to reduce the number of neutrons captured in the control rods), etc. Tests to determine exactly which reactor configurations are critical, and how criticality is affected by changes in reactor design parameters, are very important in developing new types of reactors.

Performance of a criticality test generates the same types of radioactivity as operation of a reactor, but in extremely small amounts. A criticality test operates at a very low power level (up to a few hundred watts), and neutron levels are correspondingly very low. Thus a large number of criticality tests can be done in the same test facility without generating much activation product radioactivity. Almost all of the radioactivity generated is contained within the fuel elements of the criticality test; when these are removed, the radioactivity is removed. There have been dozens of criticality tests done at the SSFL, in seven different criticality test facilities. Table 2 lists these facilities, their facility number, location, and operating periods. A short history of their operations is given in Appendix C.

3.3.3 Manufacture of Reactor Fuel Assemblies

As part of the nuclear reactor development work performed for the government, three different reactor fuel manufacturing operations were performed at the SSFL. The first operation was the assembly of fuel

TABLE 1

REACTOR OPERATIONS AT THE SSFL

Name	Power Facility No.	Facility Name	Map Loc.**	Power Level (kwt)	Operating Period	Power Generated (Mwd)	Radioactivity at End of Operation (10^3 Ci)
KEWB	073	Kinetics Experiment Water Boiler	5C	1	7/56 to 11/66	1	6
L-85/AE-6	093	L-85 Nuclear Experimentation Reactor	4C	3	11/56 to 2/80	2	18
SRE	143	Sodium Reactor Experiment	4B	20,000	4/57 to 2/64	6700	120,000
SER	010	S8ER Test Facility	7D	50	9/59 to 12/60	13	300
S2DR	024	SNAP* Environmental Test Facility	6D	65	4/61 to 12/62	13	390
STR	028	Shield Test Irradiation Facility	6D	50	12/61 to 7/64	1	300
S8ER	010	S8ER Test Facility	7D	600	5/63 to 4/65	215	3,600
STIR	028	Shield Test Irradiation Facility	6D	1,000	8/64 to 6/73	28	6,000
S10FS3	024	SNAP* Environmental Test Facility	6D	37	1/65 to 3/66	16	220
S8DR	059	SNAP* Ground Prototype Test Facility	8D	619	5/68 to 12/69	182	3,714
				22,425		7171	135,548

*SNAP = Systems for Nuclear Auxiliary Power

**Map location refers to the coordinates of Figure 2

TABLE 2

CRITICALITY TEST FACILITIES AT THE SSFL

FACILITY NAME	BUILDING NO.	LOCATION	OPERATION PERIOD	NOTES
SNAP Critical Test	373	7G	1957-63	First SNAP-2 Criticality Tests
Organic Moderated Reactor	009	9G	1958-67	Basic Tests of Reactor Concept
Sodium Graphite Reactor	009	9G	1958-67	Basic Tests of Reactor Concept
SNAP Critical Equipment Lab.	012	7D	1961-71	Later SNAP Criticality Tests
Fast Critical Experiment Lab.	100	9F	1961-74	Started as Advanced Epithermal Thorium Reactor (AETR)
SNAP Flight System	019	7D	1962	SNAP Flight System Criticality
SNAP Transient Test	024	7D	1967-69	SNAP Transient Response Tests

elements for the SRE. The second operation was a plutonium fuel manufacturing facility, and the third was a uranium carbide fuel manufacturing pilot plant. There was also a Fuel Storage Facility, used to store the special nuclear materials (enriched uranium and plutonium) used to make reactor fuel.

The SRE fuel elements were assembled in the Engineering Test Building (Building 003) at the SSFL. Uranium and thorium metal slugs were brought into the SSFL for this. In Building 003, the slugs were loaded into metal tubes, the interstices were filled with sodium metal, and the tubes were sealed. Fuel elements for 3 cores were prepared, but only 2 cores were used. The third core was eventually shipped off-site.

The plutonium fuel manufacturing facility, named the Nuclear Materials Development Facility (NMDF; Building 055) was built specifically for development work involving plutonium, and incorporated all of the safety systems and safeguards required for such work. It was completed in 1967, and operated until 1979. Its operating history is summarized in Table 3.

The uranium carbide fuel manufacturing pilot plant was located in Building 005. It was a small scale production facility built to study the operations associated with manufacturing reactor fuel assemblies out of uranium carbide. In the pilot plant, uranium oxide was reacted with graphite to convert it to uranium carbide, and the uranium carbide was then cast into pellets, machined to the proper dimensions, and assembled into cladding tubes to make fuel assemblies. Initial operations were done with depleted uranium to check out the equipment, and then enriched uranium was used to make fuel assemblies for a critical assembly to be built at another AEC facility. Operations were completed in about 9 months, in 1967, and production was small.

The Fuel Storage Facility (Building 064) was a vault, built to provide secure storage for fissionable fuel material (enriched uranium and plutonium) used to make reactor fuel. The building was constructed above ground out of concrete and concrete blocks, to meet the AEC criteria for vaults for storage of fissionable materials. It was equipped with intrusion alarms.

3.3.4 Disassembly and Examination of Reactors and Used Reactor Fuel Assemblies

During reactor test operations, it was often necessary to examine reactor fuel assemblies and other test specimens to determine how they were performing. This involved handling and examining highly radioactive items; these operations were done remotely in the heavily shielded Hot Laboratory (Building 020, the "Hot Lab") which was built at the SSFL for this purpose. Then, when each reactor operation was completed and the reactor was no longer needed, it was removed from its

TABLE 3

OPERATIONS AT THE NMDF

Operating Period	Operations
1967 - 68	Development of Analysis Technologies for uranium-plutonium oxide fuels
4/68 - 6/69	Recycle of scrap uranium-plutonium fuel
7/68 - 6/70	Development of technologies to mix tungsten into uranium-plutonium carbide fuel
4/70 - 9/70	Preparation of samples for uranium-plutonium oxide irradiation studies
9/70 - 3/74	Idle
1974 - 1975	Bench scale tests-recovery of plutonium from simulated waste
1975 - 5/77	Mixed uranium-plutonium carbide fuel fabrication
5/77 - 11/78	Partial decontamination and clean-up
11/78 - 11/79	Fabrication of depleted uranium carbide fuel
11/79 - 10/82	Idle
10/82 - 10/86	Decontamination and decommissioning
7/87	Released for unrestricted use

operating location, disassembled, its fuel removed, and its radioactive structure cut up into pieces small enough to be shipped, and the radioactive material was shipped away for disposal. The disassembly, fuel removal, and size reduction operations also usually involved working with highly radioactive materials; many of these operations were also done in the Hot Lab. The Hot Lab has also been used for work on radioactive material which was generated outside the SSFL. This material has consisted in large part of used reactor fuel from other
B | nuclear reactors. The fuel elements were shipped into the Hot Lab, disassembled or separated from their cladding material, and the separated materials then shipped away.

The Hot Lab has also been used to manufacture sealed radioactive sources (see Section 3.3.5), to do leak checks on sources, and to do cutting and machining operations on radioactive cobalt-60.

The Hot Lab facility was completed in 1959, and has been in use since then. It is a 16,000 sq ft facility with 4 large hot cells with remote manipulators and cranes, well instrumented, plus a mock-up area,
B | operating area, and decontamination areas. It is presently undergoing decontamination and decommissioning.

The Hot Lab was used to examine fuel and/or components from the SRE, SER, S2DR, S8ER, S8DR, and S1OFS3 reactors operated at the SSFL, the OMR and SGR criticality test facilities, and the Piqua, Ohio, reactor. It was also used to declad fuel from the SRE, EBR-I, EBR-II, Hallam, Fermi, and SEFOR reactors.

3.3.5 Fabrication, Use, and Storage of Radioactive Sources

Operations at the SSFL require many instruments for detecting and measuring radioactivity, and these instruments must be calibrated periodically, using known quantities and types of radioactivity. This is done using "sources"; sealed containers which contain small measured quantities of radioisotopes. Sources are also used for some forms of radiography, for irradiation testing, and for other applications. Sources have been manufactured in the Hot Lab at the SSFL and used in various facilities at the SSFL and elsewhere. Many sources are still in use at the SSFL; they are stored in secured locations and used under carefully controlled conditions.

Approximately 140,000 curies of radioactive material (primarily promethium-147) were fabricated into sources at the Hot Lab. There are less than 1000 curies of sources stored at the SSFL, mostly in the Hot Lab.

3.3.6 Preparation of Radioactive Material for Disposal

B | The operation of nuclear reactors generates radioactive waste and other radioactive material which must be disposed of off-site. Other operations at the SSFL (fuel fabrication, reactor and fuel examination, etc.) also generated radioactive waste. Radioactive waste was prepared for disposal primarily at the Radioactive Materials Disposal Facility (RMDF), with supporting operations at the Interim Storage Facility (ISF, Building 654).

The RMDF was built in 1958, and used for fuel storage and processing solid and liquid waste for disposal, in conjunction with the operation of the SRE. It has subsequently been used to support all of the SSFL nuclear operations. It is still in use.

The facility consists of the following structures or areas:

	Building 022	Radioactive material storage vault
|	Building 021	Decontamination and packaging facility
	Building 075	Low Specific Activity waste storage
	Building 621	Source storage
	Buildings 034 & 044	Offices
B |	Building 665	Non-radioactive material storage
	Leach Field	Sanitary sewer septic tank

In addition, there used to be an incinerator and a flocculation tower at the facility, but they have been removed. The incinerator was a test installation built to determine if some of the waste (paper, plastics, fabrics) could be disposed of by burning. It was tested with nonradioactive waste, and failed to function well, so it was dismantled. It was never tested with radioactive waste. The flocculation tower was built to pretreat radioactively contaminated water to make it easier to filter. It was made unnecessary by better filters.

The Interim Storage Facility was built in 1958 to store SRE fuel elements, in 10 thimbles built in holes drilled in bedrock. It was subsequently used for storage of fuel shipping casks for other reactors (OMRE and SNAP), but was taken out of service in 1964.

3.3.7 Research on Reprocessing Used Reactor Fuel

The used fuel assemblies from nuclear reactors contain unused fissionable material, fissionable transuranics (mainly plutonium), and fission products. Rockwell developed a process to make a partial separation of used fuel, removing part of the fission products so that the material could be used again as reactor fuel. Tests were done at | the SSFL as part of this process development. These tests were done in a well-shielded "Hot Cave" located at Building 003, the Engineering Test Building. These experiments used up to kilogram quantities of uniradi-

ated uranium and thorium, and up to 100-g quantities of highly irradiated materials.

3.3.8 Operation of Particle Accelerators

There are other ways to generate artificial radioactivity besides nuclear fission. One way is to bombard a target material with atomic particles which have been accelerated to high speeds by means of a particle accelerator. A common form of particle accelerator is a "van de Graaff generator"; it uses a high-voltage electrostatic field to accelerate atomic particles to high speeds (high energy levels). Collisions of these particles with a target material (such as aluminum or tritium) can generate small amounts of radioactivity. Rockwell operated a van de Graaff generator in Building 030, bombarding tritium targets with deuterons to produce neutrons.

A second van de Graaff generator was operated at the SRE facility, generating neutrons for neutron activation analyses of materials. It was removed before the SRE facility was decontaminated and decommissioned.

3.3.9 Research Using Radioisotopes

Some of the research done at the SSFL has required the use of special radioisotopes. For these tests, small quantities of specially-prepared radioisotopes are brought to the SSFL, used in laboratories under carefully controlled conditions, and then either shipped back out or stored safely when reuse is required.

One research program which requires the use of radioisotopes is the TRUMP-S program. The purpose of the TRUMP-S program is to develop fundamental thermodynamic and electrochemical data on various transuranic materials so that processes can be developed to separate these long-lived radioactive isotopes from spent nuclear fuel. These long-lived radioactive isotopes could then be destroyed by fissioning them in a nuclear reactor or accelerator, thereby eliminating the long-term hazard associated with the disposal of spent nuclear fuel. The program will use small quantities of transuranic materials (plutonium, neptunium, and americium).

B It was originally planned to do the TRUMP-S tests in the Hot Lab at the SSFL. Now, however, the test program has been transferred to the University of Missouri. Seventy-five grams of depleted uranium, five grams of plutonium, four grams of neptunium, and four grams of americium have been ordered for the TRUMP-S program. The first three materials were received and stored in Building 064. The uranium and neptunium have since been shipped to the University of Missouri, and the plutonium will be shipped there soon.

Another research program which used a radioisotope was a corrosion

test program carried out in the Corrosion Testing Laboratory (Building 023). A pumped sodium corrosion test loop was built there, and used to study the deposition behavior of activation products (Mn-54 and Co-60) in flowing sodium so as to develop more effective traps for these isotopes. An activated piece of fuel cladding containing these isotopes was used in these tests. B

3.3.10 Miscellaneous Operations

There are two other sites, used for operations which do not fall under any of the above 9 categories, which became contaminated with radioactivity. They are the Conservation Yard and the Sodium Disposal Facility. The Conservation Yard is an outdoor area, originally used for storage and salvage of used equipment. The Sodium Disposal Facility (called the sodium burn pit) was built to clean nonradioactive metallic sodium and NaK (a mixture of sodium and potassium) off of various scrap test components (pumps, valves, etc.) before they were disposed of. It was also used to dispose of nonradioactive waste sodium and NaK, and to burn nonradioactive combustible liquid waste (oils, etc.). The facility consisted of a large, rectangular, concrete-lined pit filled with water, surrounded by a concrete slab, plus two water-filled basins and a small building (Building 886).

Components to be cleaned were placed on the slab, opened to expose the sodium or NaK, and then washed off with water. The water reacted with the sodium to generate hydrogen, which often burned in the air. Sometimes the sodium and NaK also burned. (Hence the name "burn pit.") The washed items were then often pushed into the pit, where the reaction with water continued, and then removed from the pit and pushed into one of the basins, where they were allowed to remain until all of the sodium and/or NaK was reacted. They were then retrieved and buried as nonradioactive solid waste.

The sodium-water and NaK-water reactions also generated sodium hydroxide and potassium hydroxide, which have subsequently reacted with carbon dioxide in the air to form sodium carbonate and potassium carbonate, both nonhazardous materials.

Combustible nonradioactive liquids such as oils or biphenyls (an organic material used as a heat transfer fluid) were burned near the concrete-lined pit.

Neither the Conservation Yard nor the Sodium Disposal Facility was intended for use with radioactive materials, but both were inadvertently contaminated (See Section 5.10).

3.3.11 Commercial Items Which Use Radioactivity

Rockwell also uses some common commercial items which contain radioactive materials at the SSFL, as do most industrial concerns.

These include smoke detectors and self illuminating bulbs in some safety equipment, and radiographic equipment.

4.0 REGULATION AND CONTROL OF NUCLEAR OPERATIONS AT THE SSFL

Rocketdyne (or one of the organizations now part of Rocketdyne) has been engaged in the development of nuclear power since the very beginning, when the Atomic Energy Act became law in 1946. This act provided for the development of peaceful uses for atomic energy, and made it possible for nongovernmental agencies to participate in nuclear development work as contractors. The Atomic Energy Act also established the Atomic Energy Commission (AEC) as the federal agency responsible for the development, regulation, and control of nuclear energy, and made the AEC responsible for the health and safety of its employees, its contractors' employees, and the general public. Since its first activities as an AEC contractor, all of Rocketdyne's nuclear activities have been regulated by the AEC (and its successor organizations). Also from the very beginning, Rocketdyne has had its own internal regulation and control functions in operation, implementing and enforcing the external regulations and also implementing its own safety programs. Typically, Rocketdyne's internal requirements and standards have been more stringent than those of the regulatory agencies. B

Shortly after the passage of the Atomic Energy Act in 1946, North American Aviation, Inc. (NAA; a predecessor of Rockwell International) set up an organization to investigate and pursue business opportunities in nuclear power development. During the same period, it also set up a second organization to explore rocket propulsion opportunities. The NAA nuclear group became the Atomics International Division of NAA (and later of Rockwell International) in 1955, and the rocket propulsion group became the Rocketdyne Division about the same time.

Needing a remote but accessible place to test rocket engines, NAA purchased a large tract in the Simi Hills in 1948. This became the Santa Susana Field Laboratory. Then, when AI later needed a remote site for nuclear reactor development and testing, it took over part of the SSFL (Area 4) for this work. Part of this land was optioned to the AEC for government-owned test installations. Part of the AEC-owned facilities were organized as the Liquid Metal Engineering Center (LMEC) in 1966, to do developmental work on the use of liquid metals (mainly sodium) as cooling media for nuclear reactors. The charter of the LMEC was later expanded to cover general energy-related technology in 1978, and it was renamed the Energy Technology Engineering Center (ETEC). Rocketdyne operates the LMEC/ETEC for the government; this organization has never engaged in any activities which generated radioactivity. In 1984, AI was merged into the Rocketdyne Division. Rocketdyne now operates all parts of the SSFL.

The agencies regulating the nuclear operations at the SSFL have changed over the years, just as the nuclear operations themselves have changed. Figure 3 is a time-line diagram, which shows graphically when

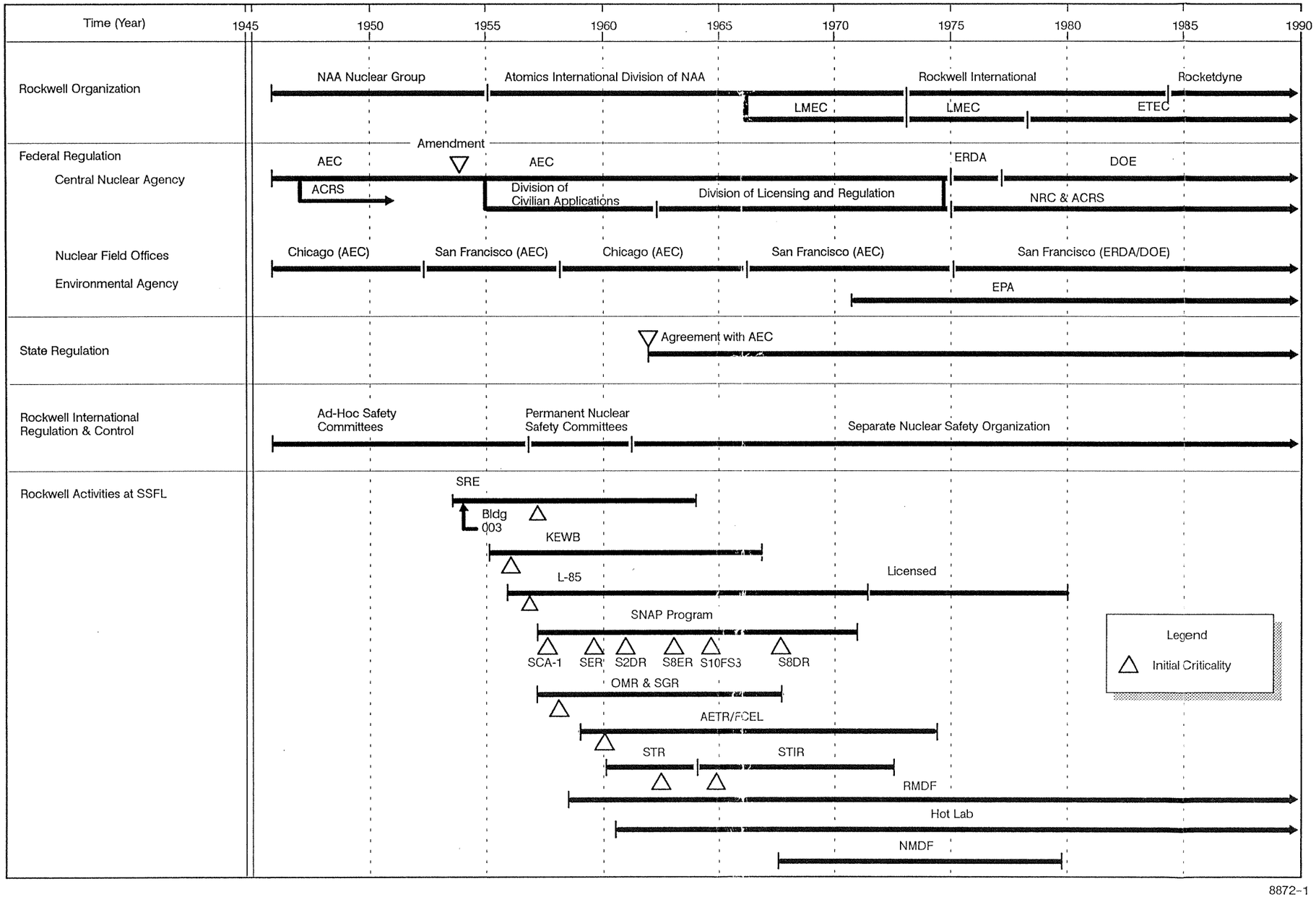


Figure 3. SSFL Timeline

these changes came about, and which regulatory agencies were acting during the major nuclear programs at the SSFL. (Event dates in the figure are approximate.)

4.1 FEDERAL AND STATE REGULATIONS

The history of the federal nuclear regulatory agency is shown in the second line of Figure 3. In 1947, one year after the AEC was established, it created the Advisory Committee on Reactor Safeguards (ACRS). The ACRS has since reviewed the safety of all nuclear reactors built in the USA, including those built at the SSFL.

The Atomic Energy Act was revised in 1954 to give private organizations access to classified information and the right to own Special Nuclear Material*. This led to the establishment by the AEC of the Division of Civilian Applications, responsible for licensing and regulating nongovernmental power reactor development, and later (in December 1957) to this becoming the Division of Regulation, which was assigned responsibility for issuing licenses for privately-owned reactors and nuclear facilities, and inspecting operations of licensed facilities.

The AEC was the federal agency responsible for both development and regulation of nuclear programs until 1975, when these two responsibilities were separated. Nuclear development became the responsibility of the Energy Research and Development Administration (ERDA), while regulatory responsibility was given to the Nuclear Regulatory Commission (NRC). The ACRS continued as an advisory safety committee to both the NRC and ERDA. In 1977, the ERDA was merged into the Department of Energy (DOE) when that department was formed. Since then, the DOE and the NRC have operated in parallel. Both organizations control the ongoing operations at the SSFL; the NRC as regulator, and the DOE, as the customer, with its own quality assurance and safety requirements.

After it was formed in 1946, the AEC established field offices around the country to help it perform its work. The field offices responsible for the operations at the SSFL are shown in the third line of Figure 3. The NAA nuclear operations were originally assigned to the Chicago Operations Office. When the San Francisco Operations Office was established (in 1952), responsibility was transferred to that office. This responsibility was transferred back to the Chicago office in 1958, and then back to the San Francisco office in 1966, where it remains.

*Special Nuclear Material includes isotopes suitable for making nuclear reactor fuel.

In 1971, the Supreme Court ruled that all nuclear facilities had to comply with the regulations of the federal Environmental Protection Agency (EPA). Since then, the EPA has exercised this authority at the SSFL. This is shown in the fourth line of Figure 3.

The Atomic Energy Act gave the federal government exclusive authority to regulate nuclear operations, but in 1961 the AEC agreed to delegate the authority and responsibility for licensing and regulating radioactive materials (excluding Special Nuclear Materials) to the states, provided that a state enacts enabling legislation and develops regulations compatible with the AEC regulations. California became an "Agreement State" in 1962. Since then, the California Department of Health Services has had the responsibility for regulating the use and disposal of byproduct material (low-level waste and radioisotopes) from the SSFL (see line 5 of Figure 3). Rockwell has had a California license for its activities at the SSFL since California became an Agreement State. In 1969, the Radiologic Health Section of the California Department of Health Services issued a broad radioactive materials license to Rocketdyne covering activities at the SSFL.

4.2 INTERNAL REGULATION AND CONTROL

Rockwell has always been safety conscious in all of its operations. Rockwell also has a corporate safety policy which requires that the safety of a program or a test be subject to critical review by knowledgeable people who do not have the responsibility for carrying out the program. To implement this policy, early nuclear operations were regulated internally by ad-hoc safety committees made up of senior management, technical, and operating personnel (see line 6 of Figure 3). These committees were selected for each separate operation, and they reviewed the proposed operation with respect to the safety of the operators, equipment, and environment. Their approval was required before the operation could begin.

In 1957, a permanent Nuclear Safety Committee was established to review the SNAP program. In 1958, additional Nuclear Safety Committees were established for the other nuclear operations. These permanent Nuclear Safety Committees functioned independently until 1961, when AI was reorganized and they were reestablished as part of a separate Nuclear Safety Organization. This organization continues to function today; it monitors and controls all activities and implements an internal review program designed to assure the safety of all nuclear operations.

4.3 REGULATORY INTERACTIONS AT THE SSFL

The major nuclear operations carried out by Rockwell at the SSFL are shown in the lower part of Figure 3.

After it was established in 1946, the AEC began a program to develop and test various types of nuclear reactors to produce electric power. One of these reactor types was a sodium-cooled, graphite-moderated reactor, the SRE. The nuclear group of NAA was awarded a contract to develop and test this reactor in 1953, and began its first nuclear operations at the SSFL in 1954 with site preparations for this reactor. The Engineering Test Building (Building 003) was built to support the SRE program in 1954; it was the first major facility built at the SSFL specifically for a nuclear program.

The SRE program and reactor design were the subject of numerous internal reviews, and this program was also reviewed externally by the AEC and the ACRS. The day-to-day AEC activities were carried out by the San Francisco field office.

The Atomic Energy Act was amended in 1954, while the SRE was under construction. The amendment gave contractors access to classified information and the right to own Special Nuclear Material. The amendment also provided for licensing non-AEC-owned reactors, the operators of such reactors, and private facilities using nuclear fuel materials and other radioactive materials. This did not affect the SRE, since it was AEC-owned, but it did make it necessary for AI to assist in the licensing of reactors it built for private owners (not at the SSFL).

Other AEC contracts led to the KEWB, L-85, SNAP and STR reactor programs and the OMR and SGR critical facility programs. All of these were license-exempt (AEC-owned); all were subject to review and monitoring internally by ad-hoc safety committees and the Permanent Safety Committees, and externally by the AEC and ACRS. The AEC operations were carried out by the San Francisco field office until 1958, and then by the Chicago office until 1966.

B | While the SSFL operations were under the auspices of the Chicago AEC office, the Hot Laboratory, RMDF, and AETR (Bldg. 100) were built. The Hot Laboratory was built on Rockwell property, but the Chicago AEC office took the position that it was license-exempt as a prime contractor facility. The RMDF was also exempt, because it was AEC-owned. The AETR, however, was not owned by the AEC. It was built on Rockwell property for the Southwest Atomic Energy Associates, an association of private electric utilities. As such, it had to be licensed, and it was. AI's nuclear fuel manufacturing operations, privately-owned and not at the SSFL, were also licensed at this time.

There was no significant difference in the regulation of licensed and license-exempt facilities. The AEC, supported by the ACRS, regulated license exempt facilities. With respect to licensed facilities, B | the AEC also developed the appropriate procedures and program requirements which formed the bases for the procedures and requirements to be implemented by the licensees.

During the AEC years, the major basis for regulating the license-exempt operations was "comparability" with the regulations imposed on licensed operations. Approvals of health, safety, and environmental protection programs were conducted using the federal nuclear regulations and general industry practice as guides. The operations licensed by the AEC (and by California, as an "Agreement State") were inspected to the federal (or state) regulations, commitments made by the licensee, and license conditions made by the AEC licensing (or the State) branch. The Agreement State regulations were required to be consistent (although not identical) with the federal regulations. Thus, all operations with radioactive material, nuclear reactors, and Special Nuclear Material were conducted according to basically the same rules.

The ERDA (and later, DOE) continued to develop more prescriptive requirements for its license-exempt operations. In nearly all cases, these were more restrictive than the existing NRC and State regulations.

In 1966, responsibility for the SSFL operations was transferred back to the San Francisco field office. This office took a different position on licensing, ruling that only prime contractor operations on government-owned facilities were exempt from licensing. This resulted in the need for licenses for the Hot Lab, the NMDF, and the operations in Buildings 005, 009, and 373, as well as for other Rockwell facilities B | not at the SSFL. A broad AEC Special Nuclear Materials license covering the operating facilities was obtained. (Nuclear operations in Buildings 005, 009, and 373 were terminated, and not included in the broad license.) Rockwell has operated its corporate-owned nuclear facilities as licensed facilities since then. A separate license was obtained for the L-85 reactor in 1972, after ownership was transferred from the AEC to Rockwell.

The San Francisco field office has since become a DOE field office; it retains oversight responsibility for the SSFL, along with the NRC, the EPA, and the California Department of Health Services.

The Decontamination and Decommissioning activities for the DOE facilities at the SSFL are being administered by ETEC through the DOE-Rockwell ETEC operating contract. Specifically the various D and D activities are identified by an Activity Data Sheet (ADS) in the DOE Environmental Restoration and Waste Management Site Specific Plan B | (Reference 4). Each ADS is funded separately by fiscal year with guidance for the activity contained in the ETEC Financial Plan. The

separate D and D tasks are administered by the ETEC Program Office, using Rocketdyne personnel to perform the work. When necessary, ETEC contracts for outside services to support the Rocketdyne personnel in performing these tasks.

To ensure the accuracy of its radioactivity measurements, Rocketdyne participates regularly in two laboratory intercomparison programs sponsored by the Department of Energy. These are the Quality Assessment Program operated by the DOE's Environmental Measurements Laboratory (EML), and the International Intercomparison of Environmental Dosimeters, also operated by EML. The first program is directed at determining the performance of approximately 40 laboratories in radionuclide measurements, primarily using gamma-ray spectrometry. The second program compares measurements of environmental levels of gamma radiation, principally by use of thermoluminescent dosimeters (TLDs). In addition, TLDs from the State of California Department of Health Services are placed at various locations with the Rocketdyne TLDs. The State TLDs are returned for analysis by an outside laboratory. All these intercomparisons show good agreement between the Rocketdyne results and the independent measurements.

4.4 RADIOLOGICAL SURVEYS OF THE SSFL

As part of its ongoing internal control program, Rockwell has carried out radiological surveys of many parts of the SSFL. These surveys were made to determine if any man-made radioactive contamination existed in areas where it was not known to be, and to locate and quantify any such contamination if it existed. A Radiological Survey Plan for the SSFL was prepared in 1985 (Reference 5); it listed the areas to be surveyed and prescribed general methods to be used to ensure that the survey results would be statistically significant and accurate and so the results would be related to acceptance limits established by the regulatory agencies.

4.4.1 Areas Surveyed

The Survey Plan listed 25 places to be surveyed. These were facilities or areas, not known to be contaminated, which had been involved in work with radioactive materials, or where radioactive materials had been stored or transported. These places are listed in Table 4, along with the rationale for their selection. They are also shown on the SSFL map in Figure 4.

4.4.2 Method

Many of the places to be surveyed were old facilities, consisting of buildings and structures with associated ventilation systems, drains, etc. Other were simply areas of open ground, and some surveys involved both. Where buildings and structures were concerned, the following

TABLE 4

RADIOLOGICAL SURVEYS AND RESULTS

Facility	Rationale	Results of Survey	Reference
Bldg 005 Area	Uranium Carbide Fuel Pilot Plant	Filter plenums, exhaust ducts, and drains contaminated	6
Bldg 064 Area	Nuclear Material Storage Vault	Cask has contamination inside. Soil contaminated in east side yard.	8
Bldg 029	Calibration Laboratory	Storage well contaminated with Ra-226.	9
Bldg 030 and 641	Van de Graaf Accelerator shipping & receiving	No contamination found	10
Bldg 513 parking lot and RA laundry area	Access path to SRE, and RA laundry	No contamination found	12
SRE storage & trash disposal	Disposal site for SRE	No contamination found	12
Old Salvage Yard	Storage area	No contamination found	11
Barrel storage yard	Storage area	Soil contamination	11
New Salvage Yard and Surroundings	Storage area	No contamination found	11
SRE to RMDF Field	Disposal site for SRE	No contamination found	12
KEWB & RMDF Field	Old reactor site (KEWB)	No contamination found	12
Bldg 049	Support for Bldg 005	No contamination found	16

TABLE 4 CONTINUED

Facility	Rationale	Results of Survey	Reference
Bldg 042	Radioactive test loop	No contamination found	16
Bldg 027	SNAP Support	No contamination found	16
Bldg 032	SNAP Support	No contamination found	16
Bldg 025	SNAP Support	No contamination found	16
Bldgs 019 and 013 and area to north-west	SNAP Critical testing (019), SNAP support	No contamination found	13
Bldg 056 Landfill	Disposal site	No contamination found	14
Bldg 626 Storage area	Storage area	No contamination found	13
23rd Street to Bldg 100 field	Storage area, trash disposal	No contamination found	14
Bldg 009	Criticality tests	Liquid holding tank contaminated inside	17
Sodium Disposal Facility	Sodium cleaning and disposal	Basins contaminated	7
Bldgs 373 and 374	SNAP criticality	No contamination found	15
Bldg 375	SNAP support	No contamination found	15
Field across from Bldg 011	Dirt disposal site	No contamination found	14

Radiological Survey

Santa Susana Field Laboratory

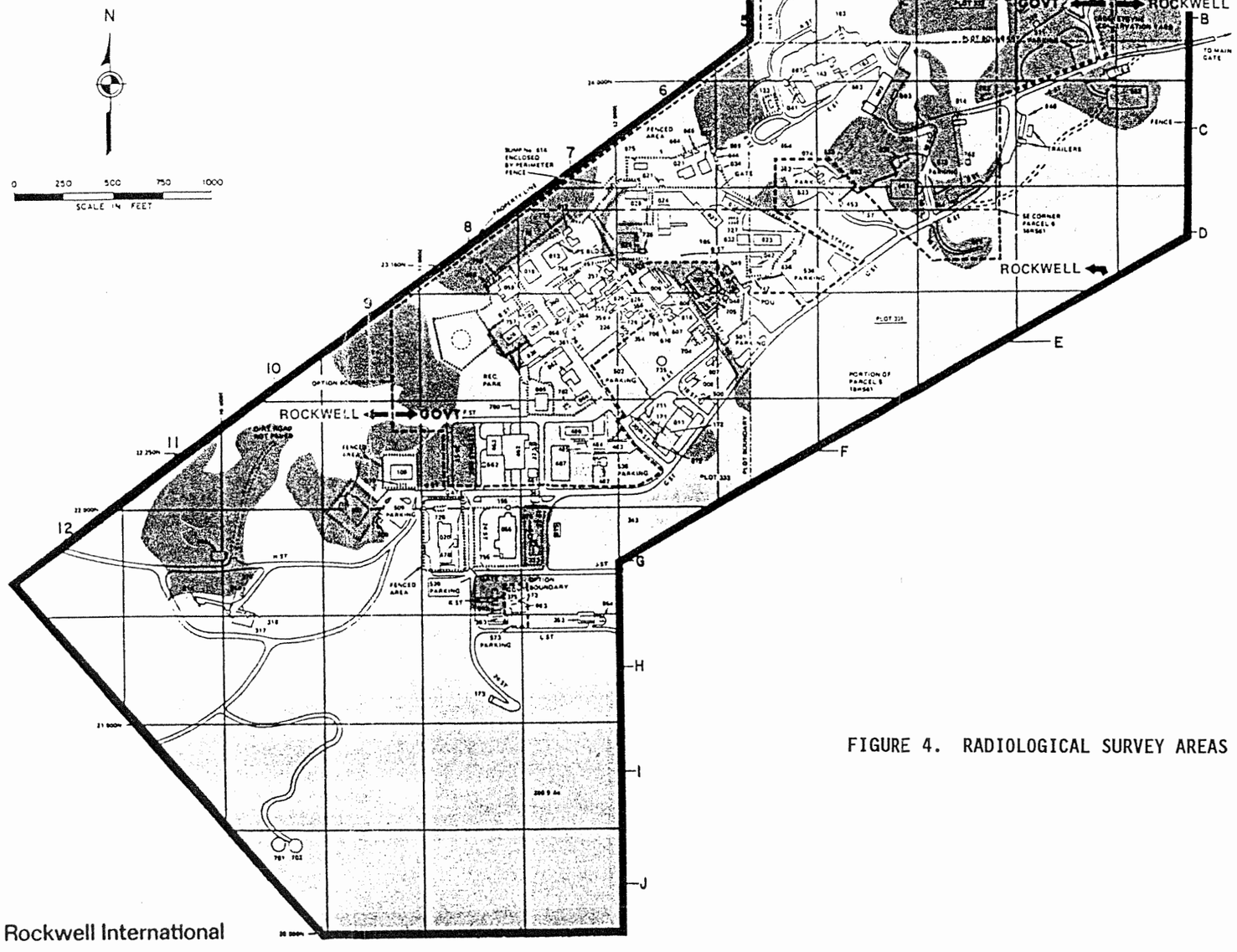


FIGURE 4. RADIOLOGICAL SURVEY AREAS

Rockwell International
Rocketdyne Division

B measurements were made:

1. Total surface alpha activity.
2. Removable alpha activity.
3. Total surface beta activity.
4. Removable surface beta activity.
5. Surface dose rate.
6. Ambient gamma exposure rate.

The measurements were made using hand-held radiation instruments to scan 1-meter-square areas of surface or the insides of vents, drains, etc. Removable activity was measured by wiping the area in question with dry filter paper, and measuring the activity picked up from the surface.

Where soil was surveyed, 2-lb samples were removed from 1-meter square areas of the surface, and then prepared and analyzed with laboratory instrumentation.

In all cases, care was taken to ensure that (1) the measurements were accurate, and (2) sufficient measurements were taken, in a proper manner, that the results could be treated statistically.

The general method and procedures used for the survey were described in detail in Reference 5.

4.4.3 Results

The surveys were carried out between 1985 and 1989, and the results published in a series of 12 reports (References 6 to 17). These results are summarized in Table 4.

Plans were made to deal with the radioactive contamination that was found. The contaminated soil was removed from the side yard at Bldg. 064 (see Section 5.3.4), and the area resurveyed. The results of the resurvey are given in Reference 20; the soil is now acceptably free of radioactive contamination (i.e., well below regulatory acceptance limits) and therefore the area is releasable for unrestricted use. The shipping cask at Building 064 will be removed and sent off site.

The contaminated storage well was removed from Building 029 (see Section 5.5), and the area resurveyed. The results are reported in Reference 19. This facility is now acceptably cleared of all radioactive contamination and releasable for unrestricted use.

The contaminated soil was also removed from the Barrel Storage Yard (called the Conservation Yard in this report; see Section 5.10.1). The resurvey of this yard is reported in Reference 18. The area is now acceptably free of radiactive contamination and releasable for unrestricted use.

B The contaminated liquid holding tank was removed from Building 009.

The contamination in Building 005 and the basins at the Sodium Disposal Facility, (as well as the contamination and activation of known radioactive sites not surveyed,) remains to be dealt with. It is discussed in Section 6 of this report; Building 005 in subsection 6.3.3, and the Sodium Disposal Facility in Subsection 6.2.3.

5.0 REMOVAL OF RADIOACTIVITY FROM THE SSFL

Rockwell's nuclear operations at the SSFL have all been of a research and development nature. The reactors have all been small, developmental types, whose test operations provided design information, either for large power reactors or for more refined space reactors. Successful tests of the power reactors at the SSFL led to larger reactors which were built elsewhere (e.g., Hallam, Nebraska and Piqua, Ohio) and which made the SSFL reactors obsolete. The space reactor program was terminated by the government in the 1970s. Because of these factors, Rocketdyne has been shutting down its nuclear facilities at the SSFL for over 15 years. During this time, it has maintained the field laboratory in a safe and secure manner, and decontaminated and decommissioned obsolete and unnecessary facilities as rapidly as program and budget constraints would allow.

The major sources of radioactivity at the SSFL have been the operation of the various reactors, the nuclear fuel manufacturing operations, and the operations in the Hot Lab. All of the reactors have been decommissioned and removed, and the highly-radioactive fuel has all been removed from the Hot Lab. Thus, two of the most important types of radioactivity, the fission products and transuranics in reactor fuel, B | have all been removed from the SSFL. The principal remaining radioactive material consists of activation products at some reactor sites, contamination at a few facility sites, and radioactive sources. The amounts of radioactive material removed from the various sites, the cost of this removal, and the resulting status of each site are described in this Section. A quantitative estimate of the amount of radioactive contamination and activation remaining at the SSFL is given in Section 6.

All of the radioactive material which has been removed from the SSFL has been disposed of in a manner in keeping with all applicable regulations.

5.1 REACTOR SITES

5.1.1 The Sodium Reactor Experiment (SRE; Building 143)

As was discussed in Section 4, the amount of radioactivity generated by a nuclear reactor is proportional to its power level. Thus, even though it was a small experimental reactor, the SRE was by far the largest source of radioactivity at the SSFL; its 20 MWt represented nearly 90% of the 22.4 MWt total of reactor power operated at the B | SSFL.

Information about the SRE operations is included in Appendix B.

B | Figure 5 is a plan view of the SRE facility during its operating period. There were a total of 12 structures on the site; the reactor building, office buildings, and supporting structures. Eight structures were directly involved in operations with radioactive materials. They were:

1. The Reactor Building (Building 143)
2. The Component Storage Building (Building 041)
3. The Temporary Hot Waste Storage Building (Building 686)
4. The Site Service Building (Building 163)
5. The Cold Trap Vault (Building 695)
6. The Liquid Radioactive Waste Vault (Building 653)
7. The Interim Radioactive Waste Storage Area (Area 654)
8. The Intermediate Contaminated Storage Area (Area 689)

The SRE operated from April 1957 to February 1964. It was shut down for the last time on February 15, 1964, and maintained in a safe shutdown condition until September 1967. At that time, the sodium coolant was drained and the core was removed and both of these items were sent off-site for disposal, and the facility was then maintained in place until 1974.

B

Decommissioning and decontamination (D and D) of the SRE began in 1974, and was completed in 1983. The D and D work cost $16.6 million, and involved the removal of over 136,000 cubic feet of radioactive waste. The entire SRE site was released for unrestricted use in 1983. Completion of this work resulted in the removal of nearly 90% of all the reactor-generated radioactivity from the SSFL. The final radiation survey was verified independently by a group from Argonne National Laboratory.

5.1.2 The SNAP Ground Prototype Test Facility (Building 059)

Building 059 was built in 1962-3, for development testing of SNAP reactors. It had two reactor test cells in its basement. Testing of the SNAP 8 Developmental Reactor (S8DR) began in the north cell in June 1968, with the reactor operating under vacuum (to simulate space flight conditions) from January to December 1969.

At the end of the test operations, the reactor core and control system were removed, sent to the Hot Lab for inspection, and then shipped off-site for disposal. At this time, sufficient D and D work was done to make a portion of the facility available for other use. The reactor cell was then sealed up, and the vacuum system prepared for storage. Further D and D of the facility (except for the reactor cell and vacuum system) was then done between June and September, 1978.

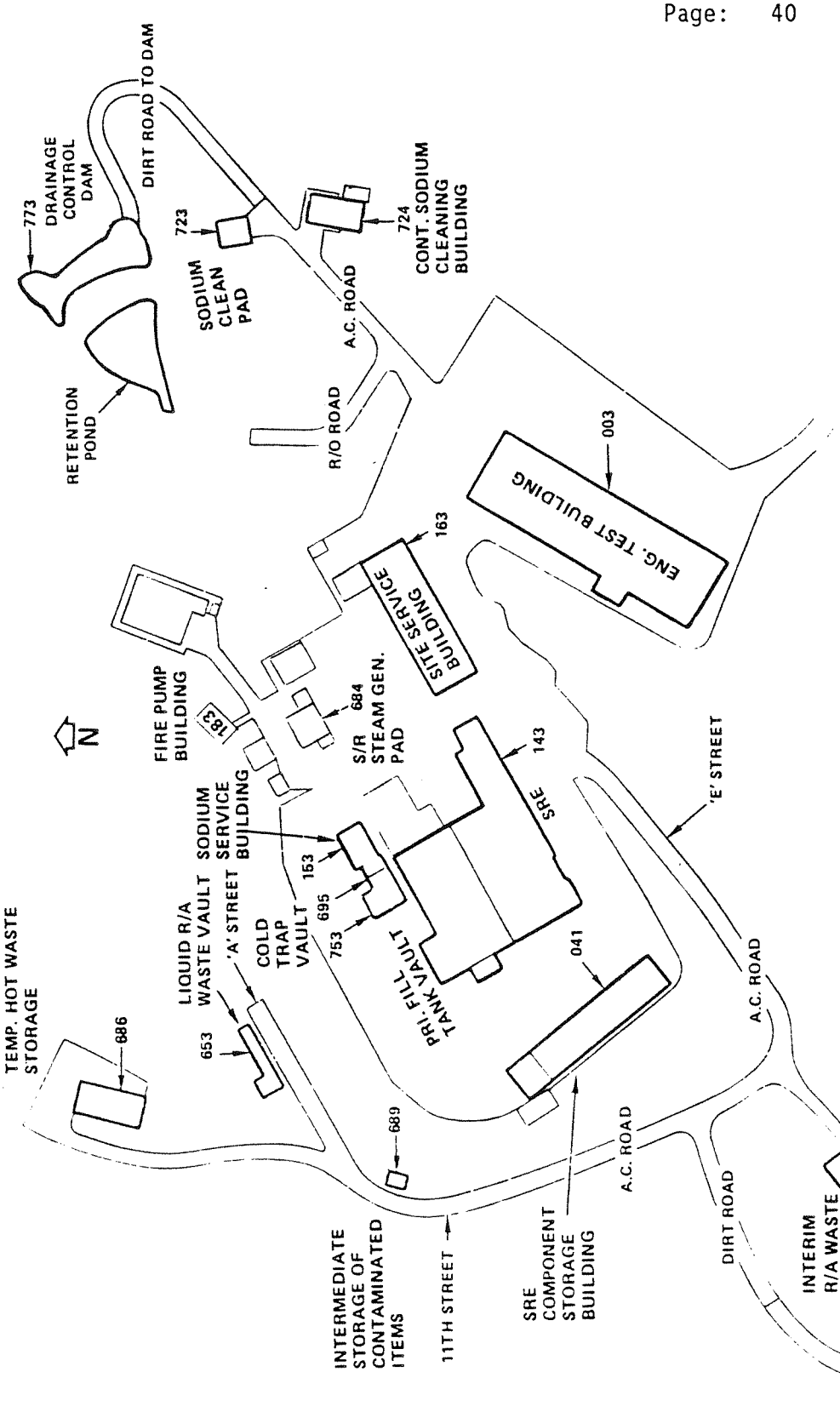


Figure 5 SRE Plot Plan

The activated below-grade part of the facility was kept sealed, and was inspected periodically. An inspection in 1983 disclosed that groundwater was leaking into the reactor vault, and becoming contaminated. Action was taken immediately to remove the contaminated water, process it, and dispose of it, and to begin a pumping program to ensure that radioactive water did not leak back out of the cell. The leak was then found and sealed, and the situation was stabilized. However, another inspection in 1987 showed the potential for structural deterioration, so a D and D program was begun to remove the remaining radioactivity.

D and D of the below-grade part of the facility has been underway since 1987. The work is being done in 2 phases. In phase 1, completed in June of 1989, the vacuum system suction pipe and its sand shielding were removed. This required removal of 4600 cu.ft. of radioactive waste, at a cost of $1,500,000.

Phase 2 involves removing the vacuum chamber and the concrete test cell walls (which contain activation products). This work is expected to generate an additional 7000 cu.ft. of radioactive waste, containing about 58 curies of radioactivity, and to cost over $5 million. Phase 2 is scheduled to be completed in 1992. At that time, it is planned to release the entire facility for unrestricted use.

5.1.3 The SER and S8ER (Building 010)

Building 010 was built in 1959 as a test facility for the SNAP Experimental Reactor (SER). The SER tests were completed in 1960, and the reactor and associated test equipment were removed, examined and disposed of. The facility was then modified to test the larger SNAP 8 Experimental Reactor (S8ER), and these tests were done between May 1963 and April 1965. The S8ER core and associated equipment were then removed, examined at the Hot Lab, and disposed of.

The facility was decommissioned and decontaminated, and released for unrestricted use. As part of the D and D effort, the building was demolished and removed. A total of 7150 cu.ft. of radioactive waste was removed, at a cost of $489,000.

5.1.4 The STR and STIR (Building 028)

Building 028 was built for the 50-kWt Shield Test Reactor (STR), and used for this purpose from 1961 to 1964. It was then modified for the higher-power (1 MWt) Shield Test and Irradiation Reactor (STIR), which operated there from 1964 to 1972. The fuel from this reactor was B | removed and disposed of, and the water from the reactor pool was drained in June, 1973. The facility was secured until September, 1975, when D and D work started. D and D was completed in March, 1976, and the facility has been released for unrestricted use.

Subsequent to the D and D work, the facility was used for arc melting of depleted uranium. This work has been completed, and the arc-melting furnace has been removed. Additional D and D work was done to clean up after this operation, and the above grade portion of the facility was removed. The below grade part of the building is again suitable for release for unrestricted use.

In the D and D of the reactor facility, 1500 cu.ft. of radioactive waste was removed, at a cost of $135,000.

5.1.5. The SNAP Environmental Test Facility (Building 024)

Two reactors (the SNAP 2 Development Reactor and the SNAP 10 Flight System 3) were operated in two different vaults in the SNAP Environmental Test Facility, Building 024, and the SNAPTRAN criticality tests were also done here. The reactors and associated equipment have all been decommissioned and decontaminated, and disposed of. About 2000 cu. ft. of material was removed, at a cost of approximately $500,000. Some activated concrete shielding remains in the vaults.

5.1.6 The L-85 (Building 093)

The L-85 reactor was operated in Building 093 intermittently, at relatively low power levels, until February, 1980. It was then shut down, removed, and disposed of, and the facility was decommissioned and decontaminated. The reactor license was terminated and the facility was released for unrestricted use on April 8, 1987.

5.1.7 The KEWB (Building 073)

The Kinetic Experiment Water Boiler (KEWB) reactor was operated in Building 073 from July, 1956, to November, 1966. This was an underground facility located adjacent to Building 093. The reactor was removed and disposed of, and the facility decommissioned, decontaminated, released for unrestricted use, and demolished, in 1975. The D and D work involved the removal of 3045 cu.ft. of radioactive waste, at a cost of $113,000.

5.2 CRITICAL FACILITY SITES

5.2.1 The Organic Moderated Reactor (OMR) and Sodium Graphite Reactor (SGR) (Building 009)

These two critical test facilities were operated in adjacent high-bays in Building 009. During their operation, there were no incidents of contamination. When the programs ended, all associated equipment was removed. Later some additional test work was done in a laboratory in this building. It resulted in some radioactive contamination, in the liquid waste holding tank system. It has been removed. B

B The east (SGR) high-bay is now used for storage of Rockwell's In-Service Inspection equipment, which sometimes becomes slightly contaminated when used for inspecting reactors operating off-site. The west (OMR) high-bay was used for tests of high-energy-rate forging (HERF), which uses a variety of materials, including depleted uranium. High energy rate forging can, under certain circumstances, increase materials strength. The developmental program conducted at SSFL yielded laboratory-sized samples to permit further study and under-standing of the technique. There was about 800 pounds of depleted uranium stored in Building 009 as part of the HERF program. It has been removed.

5.2.2 The First SNAP Critical Facility (Building 373)

B This was a building with thick walls and partitions, originally built to manufacture high-energy rocket fuels. It was used for the first SNAP reactor criticality tests from 1957 to 1963. At the end of these tests, radiation surveys were performed and the facility was released for unrestricted use. The facility was resurveyed in 1987 (Reference 15) and verified to be uncontaminated.

5.2.3 The Second SNAP Critical Facility (Building 012)

This facility was used for SNAP criticality tests from 1961 to 1971. The critical assemblies and associated equipment have all been removed and disposed of, but some activation remains in the test vault.

5.2.4 The Fast Critical Experiment Laboratory (Building 100)

This was a licensed facility used for epithermal and fast neutron criticality tests between 1961 and 1974. It was decontaminated, decommissioned, and released for unrestricted use in 1980; the facility license was terminated October 1, 1980. It is now being used for office space and for storage and use of sealed radioactive sources for instrumentation calibration.

5.2.5 The SNAP Flight System Test Facility (Building 019)

B This was built to test-qualify SNAP reactor power systems before delivery to the AEC. It was used for the criticality tests of the SNAP 10 Flight System 3 (S10FS3) reactor, before it was moved to Building 024 for power tests, and of the SNAP 10A reactor which was launched in April 1965, and its backup. This facility is not contaminated.

5.3 REACTOR FUEL MANUFACTURING SITES

5.3.1 The Engineering Test Building (Building 003)

This building was built to support the SRE. It was used for many different types of developmental tests of reactor components, as well as for assembly of SRE fuel elements (see Section 3.3.3). Research on reprocessing used reactor fuel was also done in a "Hot Cave" located here (see Section 3.3.7). D and D of this facility, including the Hot Cave, was completed in 1975. It required removal of 4200 cu. ft of waste and cost $148,000. Some traces of radioactivity were later found in the drain line from this building. It was removed, and the facility has been released for unrestricted use.

5.3.2 The NMDF (Building 055)

The activities in this building were described in Section 3.3.3. It has been decommissioned and decontaminated, and released for unrestricted use. This required the removal of 692 cu. ft of transuranic-contaminated waste and 16,527 cu.ft. of other radioactive waste, at a cost of $4.4 million. The facility was removed from the Rockwell Special Nuclear Material License on October 7, 1987.

5.3.3 The Uranium Carbide Pilot Plant (Building 005)

This building was used for uranium carbide manufacturing tests, which contaminated it with enriched uranium. The building has been decontaminated except for some ventilation system ducts and filters, and some underground piping, which remain to be cleaned up.

5.3.4 The Fuel Storage Facility (Building 064)

B Some residual radioactive contamination was confirmed to be present in the side yard outside this storage vault in a radiation survey done in 1988. Approximately 9 millicuries of old mixed fission products was removed during clean up of this yard. In removing this soil, approximately 9 millicuries of natural radioactivity was also removed. This was completed in August, 1989; 3000 cu. ft of contaminated material was removed, at a cost of $51,000. The exhaust system still contains some radioactive contamination, and there is some
B contaminated equipment inside the building. The final decontamination and radiological survey of the yard is reported in Reference 20.

5.4 THE HOT LAB (BUILDING 020)

Operation of this facility was described in Section 3.3.4. As a result of the work done in the Hot Lab, the interior of the Hot Cells and the equipment they contain have been contaminated by small amounts of uranium, plutonium, thorium, and fission products and activation products. Some exterior surfaces have become slightly contaminated as

well. The extent of this contamination is described in Section 6. The Hot Lab is also being used for temporary storage of some radioactive materials. This radioactivity will be removed when the Hot Lab is decontaminated and decommissioned. D and D of the facility has begun; it is scheduled to be completed in 1993, at a cost of $10.3 million. B | The license for this facility was changed in 1990 to limit operations to D & D work.

5.5 THE RADIATION MEASUREMENTS FACILITY (BUILDING 029)

The Radiation Measurements Facility (Building 029) was used for the storage and use of radioactive sources to calibrate radiation detection instruments for the SRE and other reactor tests. In March, B | 1964, a radium source was dropped in a storage thimble; the plastic secondary encapsulation cracked and a small amount of radium contaminated the thimble. All of the sources were removed by April, 1974, and the facility has since been used for temporary storage of non-radioactive materials. The contaminated thimble was removed and disposed of in October, 1989. Radiation survey data shows that the facility now meets the requirements for release for unrestricted use. The final decontamination and radiological survey of Building 029 is described in Reference 19.

5.6 FACILITIES FOR PREPARATION OF RADIOACTIVE MATERIAL FOR DISPOSAL

5.6.1 The Radioactive Materials Disposal Facility (RMDF)

The RMDF is still in use, and parts of it are contaminated (See Section 6.2.2). The flocculation tower and the rest of the system used to treat radioactively contaminated water has been removed. The septic tank leach field was contaminated accidentally in 1962, due to the inadvertent opening of a valve in a liquid waste system. This valve has since been removed, and the leach field has been cleaned up and released for unrestricted use. There is also a small amount of radioactive contamination on the north slope of the hill below the site. This contamination is so small that it does not represent a health threat to anyone now or in the indefinite future. Nevertheless, in the interest of preparing the site for unrestricted future use, it is being cleaned up. Other buildings at the facility are also slightly contaminated from use. Since this facility is needed to support the clean-up of all the other facilities, the facility itself will be cleaned up last.

5.6.2 The Interim Storage Facility (ISF; Building 654)

This facility was described in Section 3.3.6. After being kept under controlled surveillance for 20 years, it was decontaminated and decommissioned in 1985. A total of 4500 cu.ft. of radioactive soil and concrete plus 8, 25-ft. long tubes and baskets were removed and disposed of (a total of 5700 cu.ft.), at a cost of $270,000. The facility now meets the criteria for release for unrestricted use.

5.7 THE FUEL REPROCESSING RESEARCH FACILITY (BUILDING 003)

Fuel reprocessing research work was done in a "Hot Cave" located at Building 003. The "Hot Cave" was cleaned up as part of the D and D of the building (see Section 5.3.1).

5.8 THE PARTICLE ACCELERATOR (BUILDING 030)

The accelerator was removed in 1962 and a radiation survey made of the facility showed it to be clean. A resurvey made in 1988 confirmed that there was no activation in the building.

5.9 THE CORROSION TESTING LABORATORY (BUILDING 023)

B The radioactive corrosion test specimens and the sodium test loop have been removed from Building 023. Some slight contamination of the ventilation exhaust system and drains remains.

5.10 MISCELLANEOUS SITES

5.10.1 The Conservation Yard

A 20-by-20-ft area of the surface of the Conservation Yard was found to be slightly contaminated (total activity on the order of 0.001 B Ci) by radioactivity in 1988. A total of 132 cu.ft. of contaminated soil and asphalt was removed at a cost of $17,000 and placed in boxes to be shipped off-site for disposal. A final radiation survey was done. The radiation survey data show that the site can be released for B unrestricted use. The final decontamination and radiological survey of this area is reported in Reference 18.

5.10.2 The Sodium Disposal Facility

As was described in Section 3.3.10, the Sodium Disposal Facility was used to clean components containing non-radioactive sodium and NaK, to burn combustible nonradioactive liquid waste, and to dispose of nonradioactive sodium and potassium. This practice was stopped in the late 1970s, when the new closed-loop hazardous waste treatment facility was put into operation. However, while the facility was in use, part of the concrete-lined pit and one of the basins became slightly contaminated with fission products and very small amounts of enriched uranium.

The concrete-lined pit has been cleaned out and resurfaced, and the basins are now dry. Several areas of the contaminated basin have been dug out, and several small parts of scrap test components containing radioactivity were found and removed. Most of the buried nonradioactive waste has also been excavated and removed.

5.11 COMMERCIAL ITEMS

These items have not caused any contamination or required any cleanup.

5.12 SUMMARY

The estimated amount of material removed and the approximate cost of cleaning up the residual radioactive contamination and activation at
B | the SSFL to date are summarized in Table 5. As the table shows, Rockwell has been carrying out an energetic clean-up program ever since nuclear operations began, and has been keeping as up-to-date with clean-up as program and budgetary restrictions would allow.

B | Table 5 also shows that over $28 million has been spent to date in cleaning up radioactivity at the SSFL. This is the total of the money spent at the time it was spent; if all of this work had to be done today, it would cost much more. This is because inflation has caused costs to increase every year, and also because the cost of disposal of radioactive waste has increased at a rate greater than inflation during the past few years. Thus the money has been used very efficiently, and has resulted in most of the radioactivity having already been removed from the SSFL.

The amount of radioactive material left at the SSFL is discussed in the following section.

TABLE 5

CLEAN-UP ALREADY COMPLETED AT THE SSFL

	SITE	ESTIMATE OF MATERIAL REMOVED, cu.ft.	APPROXIMATE COST, $ *
	SRE	136,000	$16,600,000
	059	4,600	1,500,000
	010	7,100	490,000
	028	1,500	135,000
	024	2,000	500,000
	093	1,500	135,000
	073	3,000	113,000
	055	16,000 + 700 (TRU)**	4,400,000
	020	1,200 + 100 (TRU)**	3,360,000
	RMDF	2,500	500,000
	654	4,500	270,000
B	064 (Side Yard)	3,000	51,000
	Conservation Yard	132	17,000
	003	4,200	148,000
	029	50	26,000
B	TOTALS	187,782 + 800 (TRU)**	$28,245,000

Notes

*Costs are given in dollars in the years they were spent.

**TRU waste contained transuranic isotopes (TRUs)

6.0 CLEAN UP OF RADIOACTIVITY REMAINING AT THE SSFL

The plan for decontaminating and decommissioning the remaining nuclear sites at the SSFL is contained in the DOE Environmental Restoration and Waste Management Site Specific Plan (Ref. 4). The plan describes a 6-year clean up program that is already underway. The cost of the planned program is estimated at $27 million. This is almost as much as has already been spent, even though most of the radioactivity has already been cleaned up. This much higher relative cost is due primarily to the fact that the remaining work is much more expensive; the remaining radioactivity is either so dilute that a great deal of uncontaminated material must be removed along with the contamination, or it is in areas where access is difficult. As explained in Section 5.1.2, costs are also higher now than they were when much of the earlier clean up work was done. Nevertheless, the costs are quite low when compared to the projected costs for cleaning up other nuclear development sites, which have millions of times more radioactivity. (It is estimated that cleaning up the Hanford, Washington, site will cost over $50 billion, and the cost of cleaning up all DOE sites is about $150 billion.)

The approach in the Site Specific Plan is to clean up the remaining radioactive contamination at SSFL in an orderly and thorough manner. The most radioactive facilities are being addressed first, and any unconfined radioactivity is given a high priority. Facilities possessing very small amounts of contained contamination are then addressed, with the ultimate objective of releasing them for completely unrestricted future use.

B Table 6 lists all the man-made radioactivity remaining at the SSFL that requires clean up and disposition. It does not include sealed sources, waste prepared for disposal, any contamination on In-Service Inspection equipment when it is stored in Bldg. 009, or commercial items.

The Site Specific Plan is focused on cleaning up the radioactivity
B remaining as activation or contamination, at each of the sites in Table 6.

6.1 BUILDING 059

B As Table 6 shows, almost all of the activation and contamination radioactivity remaining at the SSFL is contained, and located at one site, the SNAP Ground Prototype Test Facility, Building 059. In accordance with the clean up plan, the D and D work at the SSFL is concentrating on this facility. As discussed in Section 5.1.2, a 2-phase $6.5 million clean up program was begun in 1987. Phase 1 (clean up of the vacuum system exclusive of the vacuum vessel itself) has been completed. Phase 2 (final D and D of the remaining radioactivity) is

TABLE 6

RADIOACTIVE CONTAMINATION AND ACTIVATION
REMAINING AT THE SSFL

FACILITY	CONTAMINATION AND/OR ACTIVATION, Ci
059	57.9
020	2.2
RMDF	<0.2
SODIUM DISPOSAL FACILITY	~0.001
024	~0.015
012	~0.00001
005	~0.001
064	~0.00001
023	<0.0000001

B

proceeding; it will be completed in 1992. When this is done, 97 percent of the radioactive contamination and activation that is still present will be gone from the SSFL.

The EPA gave Rocketdyne the results of a tritium analysis of the groundwater taken near Building 059. The analysis showed 1890 pCi per liter. This is far below the EPA limit for safe discharge (3,000,000 pCi/l), but apparently above background. If the tritium indeed came from Building 059, it could be from neutron activation of lithium in the concrete; it would then have had to migrate out into the surroundings. This could also be true for other former reactor sites.

Being a very weak beta emitter, tritium is difficult to detect and requires special equipment, so it is not detected during routine surveys. Since Rocketdyne had no reason to believe that any tritium would be present in the groundwater at levels requiring measurement, tritium had not been sampled for prior to receipt of the EPA analysis.

Federal and State regulations provide that if a radioactive material is present in concentrations less than one-tenth of its allowable concentration, it may be considered not to be present, and so it would not be necessary to analyze for it. This was and is true for tritium at the SSFL.

Since being informed of the EPA results, Rocketdyne has had approximately 100 SSFL groundwater samples from 45 wells analyzed by five different laboratories. Although the sampling program is not complete, current indications are that there are low levels of tritium in the groundwater at Building 059, and probably at other former reactor sites, at totally safe levels. To put this last statement in perspective, water containing 3500 times as much tritium as that in our highest sample (and 1500 times that in the EPA sample) would meet the standards for safe discharge. Also, since all reactor operations have long since ceased, no new tritium could have been generated at the SSFL for over 10 years, and any which was generated earlier is decaying away. (It has a 12.26-year half life.)

6.2 UNCONFINED RADIOACTIVITY

B The amount of unconfined radioactivity at the SSFL is small, and restricted to the Hot Laboratory, the RMDF, and the basin at the Sodium Disposal Facility. Work on cleaning this up is also underway; it is discussed below.

6.2.1 The Hot Lab (Building 020)

A number of sealed radioactive sources are stored at the Hot Lab. When these are removed, about 2.2 curies of contamination in the drain system, ventilation exhaust system, and inside the shielded cells plus

traces of contamination on the building walls and surroundings will remain. The unconfined radioactivity (outside) will be cleaned up in 1990. The remaining (confined) radioactivity will be removed and disposed of when the facility is decommissioned and decontaminated (scheduled to be completed in 1993).

6.2.2 The RMDF

Sealed radioactive sources are also stored at the RMDF. When these sources are removed, there will remain about 100 millicuries of fission product radioactivity in a liquid waste holding tank, plus small amounts of radioactivity in solid waste being stored for shipment (which varies with inventory) and less than 100 millicuries of radioactive contamination at the facility and on the slopes of the hill adjoining the facility (see Appendix D). The contamination is in the soil of the hillside and in the pavement and a drainage sump; it is scheduled to be cleaned up in 1991. The remaining radioactivity will be cleaned up when the RMDF is decommissioned and decontaminated. This is planned to be done in 1994.

6.2.3 The Sodium Disposal Facility

There is a small amount of radioactive contamination in the soil in a basin at this site. It is estimated to be one millicurie of Cs-137 and Sr-90, and less than 10 microcuries of uranium (U-235 and U-234). This will be cleaned up so that the site can be released for unrestricted use.

6.3 REMAINING CONFINED RADIOACTIVITY

The remaining radioactivity is small (about 16 millicuries), and it is confined, not loose in the environment. It will be monitored and access to it will be controlled, and that which has not decayed away will be cleaned up by the time the entire SSFL is released for unrestricted use. The contaminated sites are listed below:

6.3.1 Building 024

There are about 15 millicuries of confined activation radioactivity left in the concrete of this old reactor facility. Because of the facility's design, it would be very expensive to perform D and D and subsequently release it for unrestricted use. The confined radioactivity is decaying and will meet release criteria when the SSFL is released for unrestricted use. Meanwhile, the Company will maintain surveillance over the facility, and control access to it.

6.3.2 Building 012

The ventilation system of this old criticality test facility is contaminated (with about 0.1 microcuries of uranium). It has been

calculated that there also may be about 10 microcuries of activation radioactivity in the steel-lined concrete test cell.

6.3.3 Building 005

The exhaust ventilation system and drain lines of this facility are contaminated with about one millicurie of uranium.

6.3.4 Building 064

There is some enriched uranium contamination present in the ventilation exhaust system of this building, and on some equipment inside. The total is estimated to be about 10 microcuries.

6.3.5 Building 023

There is less than 0.1 microcurie of radioactivity left here, contained in the exhaust system and drain system.

6.4 LOST RADIOACTIVE ITEMS

There are 2 missing items, neither of which is considered a hazard. A radioactive source, containing 1.57 millicuries of Sr-90, was missing from the Hot Lab in January, 1986. An investigation concluded that it was inadvertently included in radioactive waste during a clean-up, and shipped off-site and disposed of as radioactive waste.

B In the 1960s, during tests to determine how deeply falling simulated radioisotope heat sources would penetrate the soil, a 1 kg depleted uranium slug was lost after being dropped from a helicopter. This slug has not been recovered. There is about 1 millicurie of radioactivity in the uranium and its radioactive decay products. This would not be a significant hazard even if found and not recognized, because of the small amount of material, its low specific activity, and its physical form.

6.5 SUMMARY

Excluding sealed sources, there are only about 60 curies of radioactive contamination left at the SSFL, and 97 percent of this is contained within a single reactor facility which is presently being decontaminated. Less than 0.1 curie is unconfined. In contrast, there are nearly 300 curies (3000 times as much) of natural radioactivity in the top foot of soil at the SSFL.

7.0 REFERENCES

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13. Radiological Survey of Buildings T019, T013, & T626 Storage Area, & Area Northwest of T059, T019, T013, & T012. ETEC Report GEN-ZR-0010.

14. Radiological Survey of the Area Across from T011, T056 Dumpsite Landfill, & the Field from 23rd Street to T100. ETEC Report GEN-ZR-0011.

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B

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18. Final Decontamination and Radiological Survey of the Old Conservation Yard. Rocketdyne Report N704SRR990030.

19. Final Decontamination and Radiological Survey of Building T029. Rocketdyne Report N704SRR990029.

20. Final Decontamination and Radiological Survey of Building T064 Side Yard. Rocketdyne Report N704SRR990031.

Appendix A

Radioactivity and Its Measurement

Radioactivity is a property of certain materials, both natural and manmade, in which the nucleus of the atom spontaneously emits particles and/or energy called radiation — more specifically, *ionizing radiation,* because it can produce charged particles (ions) in materials it strikes. Ionizing radiation may take the form of particles — *e.g. alpha* or *beta* particles — or waves — *e.g. gamma rays* or X-rays.

Most elements occur in different nuclear weights. Each of the different nuclear weights of a particular element is called an *isotope* of that element. These isotopes can be stable or unstable (that is, radioactive). Some of the radioactive isotopes (called *radioisotopes)* occur naturally in the soil, such as those of uranium or radium, or as a result of cosmic radiation in our atmosphere, such as carbon-14 and hydrogen-3 (called tritium). Others are the result of nuclear fission, as in a nuclear reactor, or the product of nuclear particle accelerators. Examples of such radioisotopes are strontium-90, cesium-137, iodine-131 and technitium-99m. Elements which are heavier than uranium are called *transuranics;* all of these are manmade and radioactive. Any radioactive atom may be referred to as a *radionuclide* or *nuclide.*

Measurement

The rate at which a material disintegrates is called its *activity*, which is measured in *curies*, abbreviated as Ci. One curie is equivalent to the activity of one gram of radium, namely 37 billion disintegrations per second. Lower levels of activity can be expressed as follows:

millicurie (mCi) — one thousandth curie
= 37 million disintegrations/second

microcurie (μCi) — one millionth curie
= 37 thousand disintegrations/second

nanocurie (nCi) — one billionth curie
= 37 disintegrations/second

picocurie (pCi) — one millionth of a millionth curie
= .037 (37 thousandths) of a disintegration/second

Another characteristic measured is the longevity of the radionuclide — that is, how long it takes to decay — which is expressed as *half-life*: the period of time it takes a given amount of radioactivity of the substance to be reduced by half. A rough rule of thumb is that it takes 10 half-lives to decay to an insignificant level of radioactivity. Among the radioisotopes are half-lives ranging from seconds as in nitrogen-16 to billions of years, as in uranium-238. Low-level radioactive wastes typically have half-lives ranging from a few hours to 30 years. An exception is carbon-14 with a half-life of 5,770 years, which may be disposed as LLRW in concentrations up to 8 Ci per cubic meter.

Exposure

Another set of terms is used to measure the amount of energy absorbed from ionizing radiation, referred to as the *dose.* The absorption of energy into air, defined specifically for x-rays and gamma rays is measured in *roentgens* (R) or milliroentgens (mR) — 1/1000 R. The term *rad* (radiation absorbed dose) represents the absorption of 100 ergs of energy per gram of material; for lower doses the millrad (mrad) — 1/1000 rad — is used.

Most useful for measuring biological exposure to radiation is a third unit that takes into account the different degrees of damage produced by equal doses of different types of radiation. The *rem* (roentgen equivalent man) is the product of the amount of energy absorbed (rad) times the efficiency of radiation in producing

damage. For example, alpha particles can produce 10 to 20 times as much damage as the same dose of x-rays, gamma rays or beta particles. Since human exposure to radiation usually involves very small doses, a more convenient unit of measure is the *millirem* (mrem), one thousandth of a rem.

Dose Rate

Radiation exposure over a period of time is called the *dose rate*. The annual dose rate to the average U.S. citizen from cosmic radiations and radioactive material in the earth is about 100 mrem/year. This dose is referred to as *background radiation*, which can vary from 60 mrem if you live in a wooden house at the beach to 145 mrem if you live in a stone house in the mountains. In one area of India the background radiation dose is 1,300 mrem/year! Included in background radiation is internal exposure from tiny amounts of naturally radioactive material ingested in our food and drink — *e.g.* a quart of milk contains about 1,200 picocuries and a quart of beer about 370 picocuries of potassium-40.

In addition to background radiation, the average American receives 75 mrem/year from medical diagnosis: the dose from a typical dental x-ray is 130 mrem per film, from a chest X-ray 10 mrem. These exposures are to one part of the body, not whole-body as from background radiation.

Risks

The effects of large-dose radiation exposure are known from studies of World War II A-bomb survivors and of researchers and others who worked with radioactive materials before the hazards were known. An acute dose of 1,000,000 mrem causes radiation sickness followed by death within one or two weeks. A single dose of 100,000 mrem causes no overt effects but a statistical increase in the probability of such delayed effects as cancer, birth defects, cataracts and shortening of life span. If the reproductive organs are irradiated, genetic mutations may occur in the offspring.

For doses below 1,000 mrem (1 rem) clinical effects are not measurable by current technology, nor is there yet any way of assessing the cumulative effects of low doses such as background and medical radiation. Extrapolating from high-dose data, scientists can estimate the likelihood of increased cancer rates in a given population for a specific exposure. Such a risk estimate is that in 1,000,000 persons each receiving an acute dose of 1,000 mrem above natural background exposure there would be 100 additional cancer deaths of all kinds in addition to the nearly 200,000 cancer deaths expected in that population from all other causes. For a one-time exposure of 100 mrem above background the theoretical increase would be 10 deaths.

Limits

Standards for protecting the public against ionizing radiation are developed by the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) and enforced by the Nuclear Regulatory Commission (NRC). For example, the maximum permissible dose for workers exposed to ionizing radiation as an occupational risk is 5,000 mrem per year to the whole body and 75,000 mrem per year to hands, forearms, feet and ankles.

By contrast with these limits, the maximum permissible yearly dosage to the general public is 500 mrem/year, with a recommended average of 170 mrem/year. These limits are in addition to background radiation and medical x-rays.

The NRC's performance objectives for LLW disposal facilities in 10 CFR Subpart C, Section 61.41 read as follows:

> Concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants or animals must not result in an annual dose exceeding an equivalent of 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public. Reasonable effort should be made to maintain releases of radioactivity in effluents to the general environment as low as is reasonably achievable.

End

APPENDIX B

NUCLEAR REACTOR OPERATIONS AT THE SSFL

A brief discussion of each nuclear reactor operation at the SSFL is given below, in chronological order by start-up date.

1. The Kinetics Experiment Water Boiler Reactor (KEWB)

This was the first nuclear reactor to be operated at the SSFL. It was a small research reactor, using a water solution of uranyl sulfate as fuel. Two different cores were used: the first core was a spherical tank, and the second was a cylindrical tank. The cores were enclosed in a cube of graphite approximately 5 feet on a side. The graphite cube, contained in an aluminum box, was installed in a specially designed concrete vault (Building 073) built underground. The reactor was used to study the dynamic behavior and inherent safety of homogeneous, water-boiler type reactors. The reactor started up with the spherical core in July 1956, and later operated with the cylindrical core. It was shut down for the last time in November 1966. Most operations were at very low power (1 kWt or less), but the reactor was operated briefly at 50 kWt. The final use was as a neutron pulse test facility, for many different tests.

2. L-85 (AE-6) Research Reactor

This was a small, low-power research reactor, which started life (in Building 093) named the AE-6. The core, made up of a solution of uranyl sulfate in a spherical tank, was surrounded by a graphite reflector. This reactor had a homogeneous, solution-type core as did the KEWB, but it could operate at up to 3 kWt (still a very low power level). It was used as a neutron source for many different tests, and for reactor operator training. Rockwell supplied similar reactors to several universities, for similar purposes. The reactor operated off and on for 24 years, from November 1956 to February 1980.

3. The Sodium Reactor Experiment (SRE)

The Sodium Reactor Experiment (SRE) was designed by the group which later became Atomics International, a division of Rockwell International, as a part of a program with the Atomic Energy Commission (AEC) to develop a graphite-moderated, sodium-cooled, power reactor for civilian application.

The SRE site was located at map coordinates 4B of Figure 2. The reactor was designed and constructed by AI and the AEC to demonstrate the feasibility of a high-temperature, sodium-cooled, graphite-moderated reactor as the heat source of a central power station. It was the first civilian nuclear reactor in the United States to produce power for supply to a commercial power grid. The SRE was a 20-MW thermal reactor

using slightly enriched uranium metal fuel in the initial core loading. The fuel was in the form of stainless-steel-clad rods with sodium bonding in the annulus between the fuel and cladding. The active core length was 6 ft. Heat generated in the reactor was transported by a primary sodium cooling system to a heat exchanger, and then by a secondary sodium system to a steam generator, which then powered a steam turbine and generator provided by Southern California Edison Co.

Intensive design of the SRE began in June 1954, and construction of the plant began in April 1955. Construction was completed in February 1957, and the ambient temperature subcritical experiment, without sodium in the core, was started on 23 March 1957. On 25 April 1957, the SRE was brought to criticality with 350°F sodium in the core. The reactor was brought to full power in early May 1958, and operated until February 1964. During this time, it generated 37,000 MW hours of electrical power in more than 27,000 operating hours.

The reactor underwent an accidental partial blockage of sodium coolant in some reactor coolant channels in July 1959. This resulted in the partial melting of several of the reactor fuel assemblies and the release of some fission products that contaminated the reactor cooling system. All of the reactor safety systems functioned properly, and the reactor was safely shut down. The reactor fuel assemblies were then removed, inspected, and stored at the RMDF. (They were later declad in the Hot Lab, and the fuel and cladding was shipped off-site.) A second fuel loading was inserted, and the test operations were continued.

Two of the fission products which were released from the damaged fuel elements were xenon-135 and krypton-85. These are inert gases, which contaminated the protective reactor cover gas system. The cover gas was transferred to a holding tank and held long enough for the xenon-135 to decay away (9.2-hour half life), and then released to the atmosphere through the stack in a controlled manner, in concentrations which met AEC requirements. Based on measurements of the cover gas concentration and volume, less than 5 curies of krypton-85 (10.8-year half life) were released in this way. The dispersion of the krypton-85 in the atmosphere diluted it so much that it would have resulted in a maximum theoretical calculated dose* of 0.06 micro-rem to someone living in Susana Knolls, the nearest residential area at that time. This is equivalent to the dose received from natural background radiation in approximately 15 seconds; a negligible amount. The other fission products were all retained in the primary sodium coolant, and were removed during cleanup operations.

This incident at the SRE was made public at the time, but it received little notice.

*See Note at end of Appendix

4. The SNAP Experimental Reactor (SER)

Beginning in the late 1950s and extending into the early 1970s, Rockwell carried out a major program to develop space nuclear power systems, the SNAP (Systems for Nuclear Auxiliary Power) program. The centerpiece of the program was the uranium-zirconium hydride reactor, in which fully enriched uranium was dispersed in fuel rods containing hydrogen at about the density in water. The reactor was controlled by movable segments in a beryllium reflector sleeve and was shielded by lithium hydride. The major advantage of the concept was its compactness.

Four versions of SNAP reactor systems (SNAP 2, SNAP 4, SNAP 8, and SNAP 10A) were developed by Rockwell for different power levels and using different power conversion systems.

The SER was a prototype basic SNAP reactor, operated in Building 10 at a power level of 50 kWt, for power demonstration and endurance tests.

5. The SNAP-2 Development Reactor (S2DR)

This was a prototype of the SNAP 2 reactor, which was tested at a nominal power level of 65 kWt without any power conversion system equipment. The reactor was tested in Vault 1 of the SNAP Environmental Test Facility (Building 024).

6. The Shield Test Reactor (STR)

This was a reactor used primarily to generate radiation fields for shielding tests of SNAP reactors. It started life as the Shield Test Reactor (STR) with a power rating of 50 kWt; in 1964, the reactor was modified to raise the power rating to 1000 kWt, and it was given a new name (STIR; see 9 below). The 50-kWt core was fueled with SNAP reactor fuel elements. It first went critical in December 1962. In addition to shielding tests, tests were also done to study radiation damage to electronic systems, and to qualify reactor hardware for SNAP reactors.

The reactor was installed in a tank of water in Building 028.

7. The SNAP 8 Experimental Reactor (S8ER)

This was a prototype SNAP 8 reactor, the first in a series of reactor tests to be performed to develop a flight-qualified SNAP 8 reactor. The SNAP 8 Experimental Reactor was a compact, 600-kWt reactor installed in Building 010. It was cooled by flowing NaK, a liquid alloy of sodium and potassium metals.

8. The SNAP 8 Developmental Reactor (S8DR)

This was a second prototype SNAP 8 reactor, tested in a vacuum to simulate the space environment. A vacuum system and vacuum chamber were installed in a vault in the basement of Building 059 for this test program.

9. The Shield Test and Irradiation Reactor (STIR)

This was a rebuild of the Shield Test Reactor (in Building 028) to increase its power level for testing purposes. A new core fueled with Materials Test Reactor fuel elements was installed. (The Materials Test Reactor was built in Idaho.) This increased the maximum rated power level to 1 MWt.

10. The SNAP 10 Flight Simulation Reactor (S10FS3)

This was a SNAP 10 reactor, tested at power (37 kWt) for reliability and performance. It operated in Building 024 continuously for 10,000 hours.

*Note on Dose Calculation from release of krypton-85.

The dose to the public was estimated by use of the EPA computer program, AIRDOS-EPA, which calculates the exposure concentration due to release of airborne radioactive material. This program uses typical meteorological data, which shows the wind direction to vary. However, in order to calculate a maximum possible dose, the results were adjusted to find the dose at the nearest existing community (Susana Knolls), assuming that the wind blew only in that direction. The result, which also assumed no shielding by houses, cars, or clothing, was 0.06 microrem. This is the amount of dose received from natural external radiation in about 15 seconds.

APPENDIX C

CRITICALITY TEST FACILITY OPERATION AT THE SSFL

1. The (First) SNAP Critical Test Facility (Building 373)

This was a critical test facility constructed in a building originally built to make high energy rocket engine fuels. It was used for tests of five SNAP reactor critical assemblies (SCA-1, S2ERC, SCA-2, SCA-3, and SCA-4C) between 1957 and 1963. It was later replaced by SNAP Critical Test Facility (Building 012), which was built specifically as a critical test facility.

2. The Organic Moderated Reactor (OMR) Critical Facility (Building 009)

This was a low-power critical experiment facility, used for testing reactors moderated and cooled by organic liquids. The critical assembly core used slightly enriched uranium fuel in a heterogeneous, organic-moderated lattice. Various types and configurations of fuel elements and core geometries were tested.

3. The Sodium Graphite Reactor Critical Facility (SGR) (Building 009)

This was also a low-power critical experiment facility, which operated in the same building as the OMR. It was used to determine the operating characteristics of reactors with cores cooled by sodium and moderated with graphite. The basic critical assembly was a cylindrical array of hexagonal graphite cylinders into which various amounts and configurations of fuel and sodium (in cans, or simulated by aluminum) could be inserted.

4. The (Second) SNAP Critical Test Facility (Building 012)

This facility was built to continue criticality testing of SNAP reactors. Three SNAP reactor critical assemblies (SCA-4A, SCA-4B, and SCA-5) were tested here for the AEC between 1961 and 1967, and additional criticality tests of space reactor configurations were done here for NASA through 1971.

5. The Fast Critical Experiment Laboratory (Building 100)

This started life as the Advanced Epithermal Thorium Reactor (AETR) Critical Facility, built for the Southwest Atomic Power Association, an association of private utility companies. It was a very versatile facility; 20 different reactor core configurations were studied in it. The early tests were of thorium- or uranium-fueled reactors which operated with neutrons of intermediate energies (epithermal flux spectra); later tests were of reactors with high-energy (fast) neutrons.

6. The SNAP Flight System Critical Facility (Building 019)

Also called the Acceptance Test Facility, this facility was built to do criticality acceptance tests of SNAP reactors before they were to be delivered to the DOE for launch as space power systems. The criticality tests of the S1OFS3 reactor were done here, in 1963, before it was operated in the SNAP Environmental Test Facility (Building 024). Criticality tests of other flight-qualified SNAP-10 reactors were also done here.

7. The SNAP Transient Test Facility (Building 024)

This was a criticality test facility set up in the same building as the SNAP Environmental Test Facility, where the S2DR and S1OFS3 reactors were tested. It was used to test the response of a SNAP reactor to rapid changes in control drum position, at low power. This was the SNAPTRAN test; the reactor criticality responses were studied at the SSFL, and then the reactor was moved to Idaho for power testing.

APPENDIX D

B

ESTIMATE OF UNCONFINED RADIOACTIVITY AT SSFL

It is estimated that there is no more than a few tens of millicuries of unconfined radioactivity at the SSFL (1 mCi in the burn pit, 10-20 mCi at the RMDF, a few mCi at the Hot Lab). However, to calculate an upper bound on this radioactivity, it was assumed that 1 acre-foot of soil would have to be removed (this is double the actual present estimate) and that this soil would contain 50 pCi/gram of radioactive contamination (reasonable for truly contaminated soil, but very high as an average for all the soil to be removed). With these values, and assuming a soil density of 100 lb/cu ft, there would be a total of 100 x 10^{-3} curies or 100 mCi.